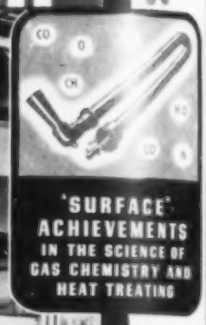
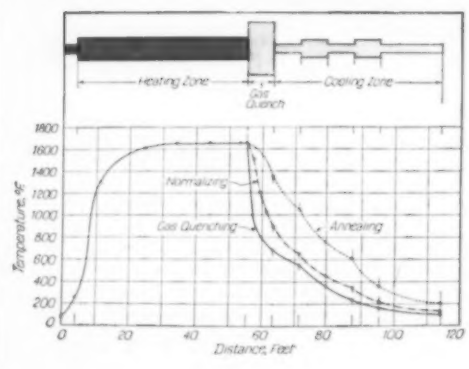
METAL
PROGRESS

Atmosphere Gas Quench*



The "Bright Gas Quenching" zone of a 'Surface' installation in a leading tube mill.

THE RESULT:



The result accomplished by "Bright Gas Quenching" with the Super-Fast Cooling Zone is shown by the above curves.

has many possibilities of application where rates, faster than air cooling, are necessary to produce higher physical properties as well as a clean, bright metal surface.

● 'Surface' developed the "Bright Gas Quenching" process as a means of producing the desired physicals in S.A.E. X-4130 and NE 8630 Welded Aircraft Tubing in quantities sufficient to satisfy the increasing demand for greater aircraft production. The problem was difficult because of cold rolling and welding operations. Also the heat-treated surface had to be clean and bright.

By utilizing a chilled, bright-annealing atmosphere, recirculated at high velocity through a series of gas nozzles located above and below the work, the aircraft specifications for the tubing were met. A Super-Fast Cooling Zone is located immediately adjacent to the discharge end of the radiant tube heated furnace, and this zone is followed by a cooling zone for cooling the gas quenched tubes to below the discoloration point. Large production of welded aircraft tubing has been made possible. Cleaning and pickling have been eliminated. Naturally, costs have been greatly lowered.

A bulletin is available on "Bright Gas Quenching"—also bulletins on the application of atmospheres to most common heat treating processes. Write for them.

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December, 1945
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Metal Progress

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Ernest E. Thum

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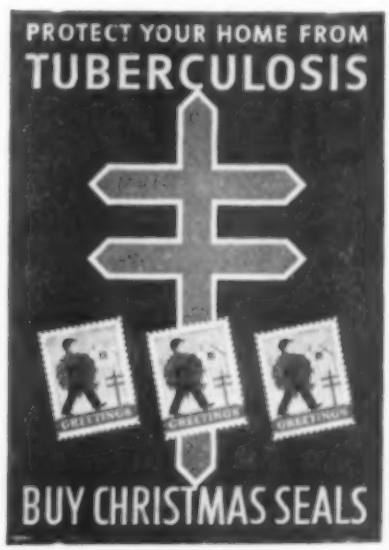
The beautiful kodachrome of stainless steel Christmas gifts used on the cover was given to Metal Progress by Electro Metallurgical Co.



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Bright Annealing of Nickel and High Nickel Alloys

By E. M. Kline
and R. K. Gensler
Metallurgists
Huntington, (W. Va.) Works
International Nickel Co., Inc.

FOR the purposes of this article, the expression "high nickel alloys" refers specifically to alloys of nickel and copper, nickel and chromium, and nickel, chromium and iron, in all of which nickel is the major constituent; "bright annealing" is defined as a combined heating and cooling process, for complete stress relieving, which yields a metallic surface substantially unchanged in appearance or quality, when starting with a clean and lustrous surface as produced in cold-working operations. For example, if a specimen of cold-rolled nickel or high nickel alloy strip is heated in air, the surface quickly becomes discolored with an oxide coating. However, if the same specimen is both heated and cooled in a "proper" bright annealing atmosphere, the bright surface resulting from the previous cold working would have been unaffected.

For example, a "proper" bright annealing atmosphere for nickel or Monel (an alloy containing approximately 67% nickel and 30% copper) could be the products of combustion resulting from the burning of natural gas with such a deficiency of air that the resulting gas contains appreciable concentrations of carbon monoxide and hydrogen, say of the order of 4 to 6% *in toto*, but with no free oxygen present. Although such gases or "atmospheres" contain appreciable concentrations of both carbon dioxide and water vapor, it so happens that these two compounds do not discolor nickel or Monel through the formation of stable oxides during the annealing process. Another example would be a gaseous atmosphere of nitrogen with a small amount of hydrogen — at least enough hydrogen to react with and "fix" the oxygen content of any air which might be carried into the annealing chamber by leakage or adsorbed on the surfaces of the metal.

A "proper" bright annealing atmosphere for nickel-chromium alloys such as "Inconel" (containing approximately 80% nickel and 13% chromium) is one in which oxidizing constituents such as carbon dioxide and water vapor, as well as free oxygen, are *absent* — otherwise the metal would be discolored by stable oxides forming on the surface during the cooling cycle when the metal is within the temperature range wherein oxidation occurs but reduction of oxides, the counteracting process, cannot. Consequently, for bright annealing such alloys an atmosphere of pure hydrogen or a mixture of nitrogen and hydrogen, with the latter as the major constituent, is preferred. Such gaseous atmospheres should be dried to a dew point of at least −60° F. (−50° C.) before entering the furnace and, as an added safeguard against contamination from small concentrations of free oxygen, it is advisable to pass the gas or gases over a heated copper catalyst prior to drying.

The annealing facilities provided at the Huntington Works of International Nickel Co. when this plant was brought into production in 1922 were composed entirely of the conventional box or retort annealing units similar to those used in the steel industry. The so-called reducing atmosphere for avoiding oxidation during the cooling cycle was derived from charcoal placed inside the retorts. All products such as sheet, strip and cold-drawn rods were annealed in this manner.

In 1926, Huntington Works pioneered in the field of bright annealing sheet stock by installing the first continuous furnace embodying heating and cooling in a controlled atmosphere. In this installation, a portion of the products of combustion of the natural gas used for heating the furnace proper, intentionally combusted with a deficiency of air, constituted the atmosphere in

the water-cooled cooling chamber. No auxiliary cooling of the products of combustion used during the cooling cycle, such as pumping the gases through a heat exchanger, was provided; the atmosphere in the cooling chamber was controlled by maintaining just sufficient positive pressure therein to prevent infiltration of air around the shaft seals and at the discharge end. This unit — still in operation — is about 175 ft. long (inclusive of approximately 75 ft. of cooling zone) by approximately 6 ft. wide on the inside. The work is conveyed by heat resisting alloy wheels mounted on a series of water-cooled shafts spaced at approximately 12-in. intervals. The rate of travel can be varied at will from about 7.5 to about 30 ft. per min.

In addition to handling our production of sheet, this furnace was utilized for final annealing of that portion of the Monel and nickel strip which was not to be shipped in coils. The furnace, of course, was not designed for handling products other than flat stock.

Products other than sheet and strip in straight and cut lengths continued to be handled in the box annealing units. However, the use of charcoal as a means of producing an annealing atmosphere within the box was discontinued in favor of a gaseous atmosphere derived from the products of combustion of natural gas with a deficiency of air (and, alternatively, with an atmosphere of approximately 90% nitrogen and 10% hydrogen).

In 1930 and 1931, research was being directed toward the development of the nickel-chromium alloy introduced to the trade in 1932 as Inconel (80 Ni, 13 Cr, 7 Fe). As a part of this research program, experimentation was carried out for a suitable means for bright annealing the alloy, particularly in the form of strip for which there appeared to be an immediate potential market. For the reasons indicated previously, the alloy could not be bright annealed in either the box annealing units or the "new" continuous sheet annealing furnace.

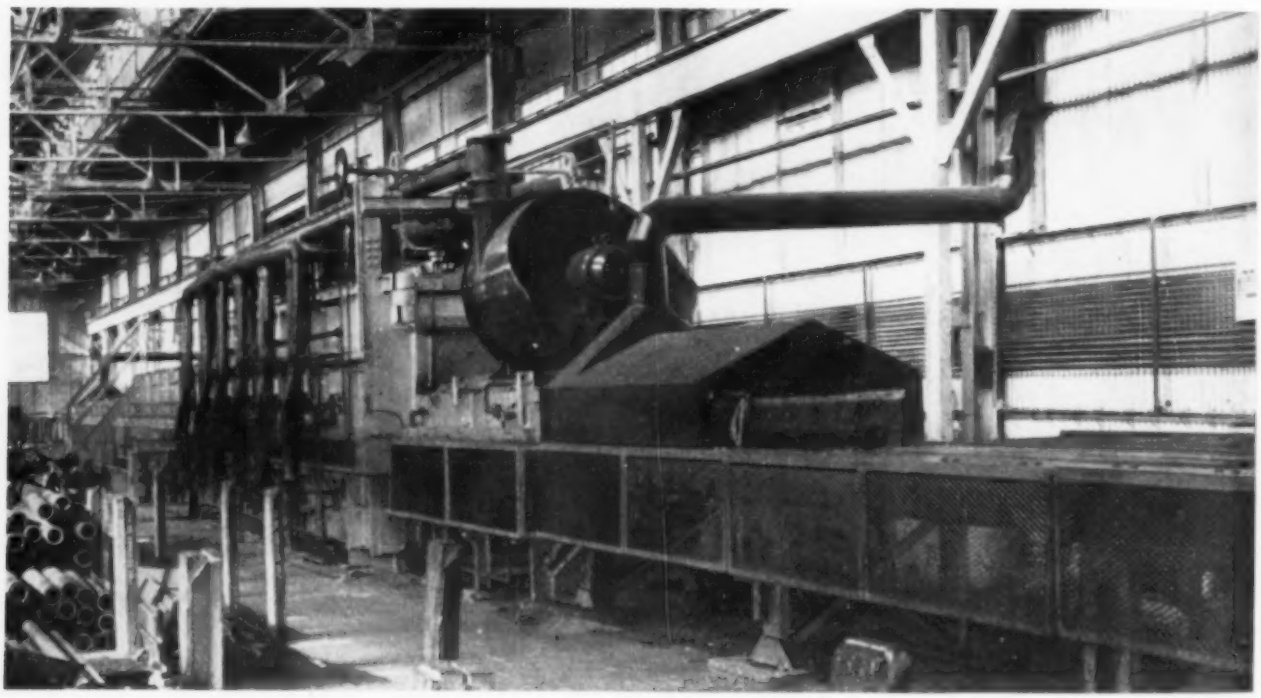


Fig. 1 — Roller Hearth Furnace for Annealing of Bars and Tubes in Mill Lengths, Heated by Banks of Radiant Tubes Both Above and Below the Work. Protective atmosphere is vigorously circulated by external and internal fans

The first bright annealing procedure worked out for Inconel involved a passivation treatment by immersion in hot dilute nitric acid prior to annealing, as disclosed in U. S. Patent No. 1,901,039.

Experimentation was continued, however, with a view to finding a process more adaptable to commercial production. This led to the discovery that, in a reducing atmosphere maintained substantially free of constituents oxidizing in respect to Inconel, not only could the alloy in bright form be bright annealed but the alloy in oxidized form also could be bright annealed — that is to say, the surface oxides could be com-

pletely reduced. Although the preferred atmosphere was pure hydrogen dried to a dew point of at least −60° F. (−50° C.), it was found that hydrogen diluted with nitrogen by synthetic blending, or by burning hydrogen gas with a deficiency of air, or as derived from cracked ammonia, were likewise satisfactory. It was also found that atmospheres of either pure carbon monoxide or pure carbon monoxide diluted with nitrogen (both dried to a dew point of at least −60° F.) were reasonably satisfactory.

The problem then resolved itself into one of designing a production unit of the continuous type in which the proper atmospheric conditions could be maintained throughout the heating and cooling cycles. The bright annealing of nickel-chromium alloy strip in thicknesses up to ¼ in. and widths up to 8 or 9 in. was something that the commercial furnace builders had not attempted and, therefore, no suitable units were available in the market.

Because the highly reducing annealing atmosphere required was such as would react with ordinary refractories at the annealing temperatures, thus producing compounds oxidizing in respect to Inconel, it was essential that the metal to be annealed be conveyed through a metallic muffle. It was, at the same time, necessary to deliver a product as free as possible from surface blemishes which would be the natural consequence of contact between work and muffle during transit. Consideration of the merits and demerits of vertical furnaces versus horizontal furnaces for this particular application led to the conclusion that the latter was preferable. A novel solution to the conveying problem was finally reached by designing a flexible and jointed hearth of graphite blocks extending from end to end of the heating and cooling chambers. This avoided metal-to-metal contact and, since the atmosphere had to be substantially free of all *oxidizing* constituents, the hearth did not deteriorate when hot. Metal strip was drawn through the furnace by a coiler located at the discharge end.

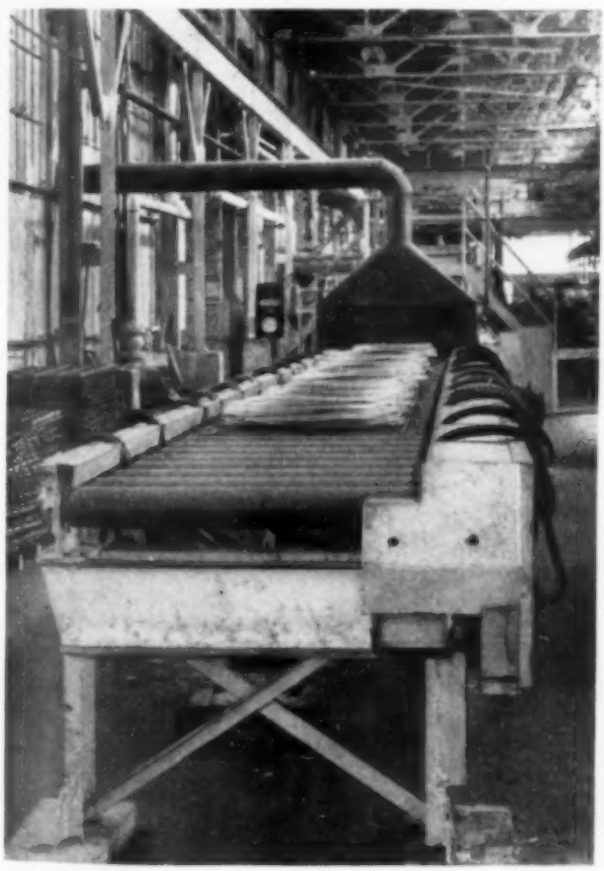


Fig 2. — Discharge Table for Same Furnace Showing How Coils Are Carried Through on Thin Metal Trays

The drying of gases to a dew point of −60° F. or better, on an economical basis, was only in its infancy in 1932. As a matter of fact, it had been anticipated that it would be necessary to resort to a rather elaborate installation using anhydrous magnesium perchlorate, together with an equally elaborate means for regenerating this expensive chemical. However, activated alumina became available almost at the same time this first furnace was constructed, and this material was tried in suitable home-made driers and it met all the requirements.

An electrolytic hydrogen plant, installed previously for another purpose, furnished an ample supply of hydrogen requiring only a slight degree of purification. This was done by passing the gas over a heated copper catalyst prior to drying. In order to assure the highest purity of gas for the cooling cycle (when the metal would be at temperatures above that at which oxidation could take place but below that at which reduction of oxides could be accomplished) the atmosphere was circulated counter-current to the travel of the metal being annealed. It was under sufficient positive pressure at all times so that the impure gases resulting from reaction with the air carried into the furnace with the incoming metal was washed out continuously at the inlet end.*

There are currently five of these units in service at Huntington Works for the bright annealing of Monel, nickel and Inconel strip. (See the view on the next page.) For Monel and nickel an atmosphere of approximately 90% nitrogen and 10% hydrogen dried to a dew point of not less than −60° F. (−50° C.) is used; for Inconel an atmosphere of pure hydrogen, likewise dried to a dew point of at least −60° F., is used.

*Details of this bright annealing process are disclosed in U. S. Patent No. 2,057,518.

In each unit the heating chamber, zoned for temperature control at three points, is approximately 20 ft. long and the water-jacketed cooling chamber is approximately 37 ft. long. The metallic muffles originally provided were made of oval seamless nickel tubing approximately 9¼ x 4 in. inside dimensions. These have been replaced in later years with fabricated nickel muffles resembling in cross-section the capital letter D, with the flat side of the D making the base for the graphite hearth. This construction has enabled the muffles to be increased to 16 in. wide inside, and 20-in. wide muffles are contemplated.

Each unit is, of course, provided with gas seals at both the entry and discharge ends, suitable means for pulling the strip at predetermined constant speeds (depending upon the type of alloy as well as the gage and width involved), and suitable means for cooling the annealed strip as it is discharged.

Expanding production of cold drawn wire, tube, and rod created a need for a continuous furnace, capable of bright annealing Monel and nickel products in both intermediate and final stages. A unit satisfying these requirements was completed in December 1944.

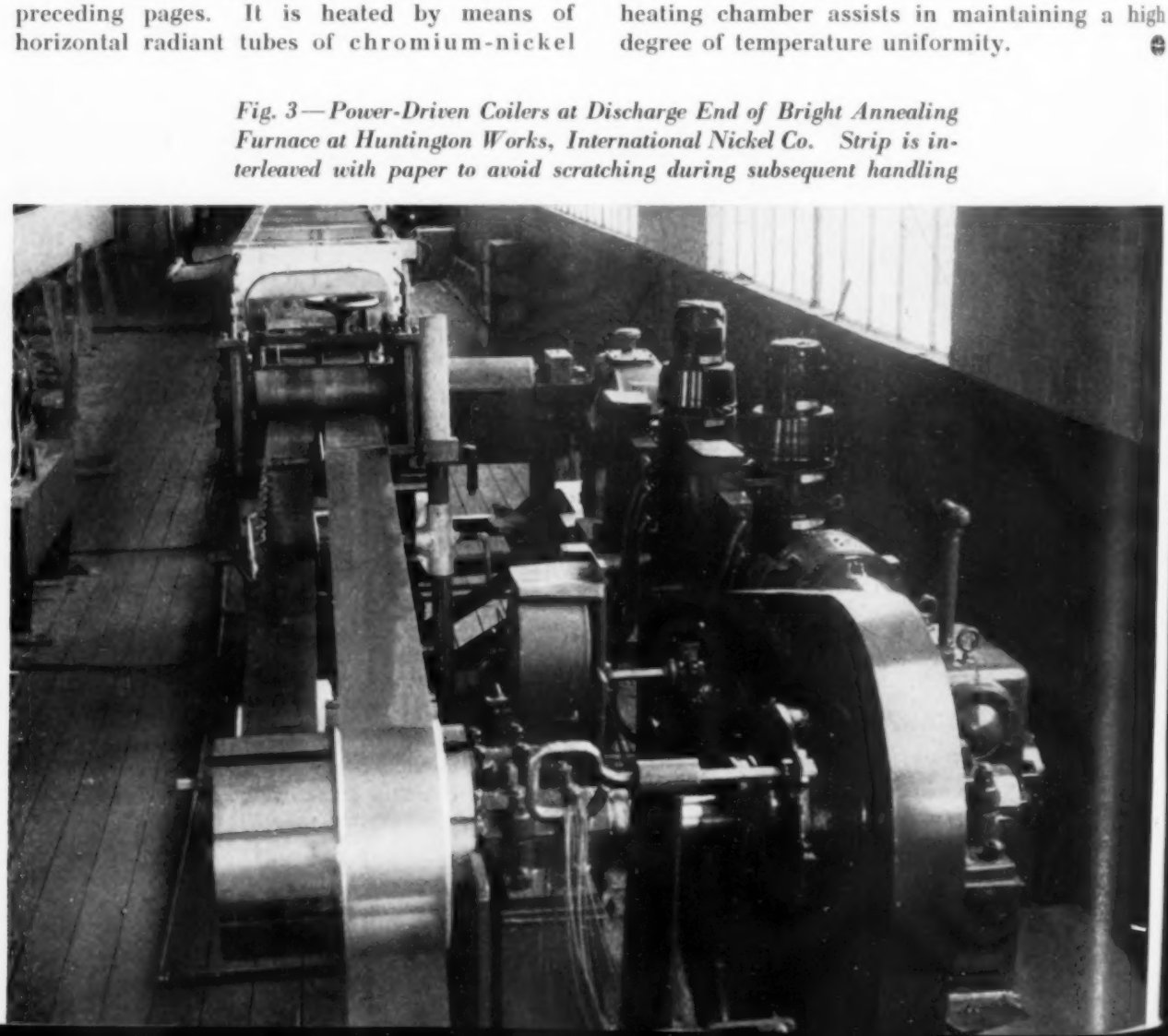
This newest furnace is shown on the two preceding pages. It is heated by means of horizontal radiant tubes of chromium-nickel alloy, placed above and below the roller hearth. Alloy rolls on 12-in. centers convey the metal at speeds of from 3 to 60 in. per min. Atmosphere is provided by an external gas producer, which burns natural gas with a controlled deficiency of air. Oxygen-free gas is thus produced which can be varied in $CO + H_2$ content from "neutral" to about 23%. The water vapor produced by combustion is condensed out to a dew point of 70° F., and the gas is not dried further.

Atmosphere in the 33-ft. heating chamber is kept in circulation by means of three alloy fans rotating in a horizontal plane, and mounted with drive shafts passing through the roof.

The first 32 ft. of the 75-ft. cooling zone is equipped with rapid-cooling features that include a direct water-spraying unit, followed by three outside fans in series which circulate the atmosphere through water-cooled heat exchangers. Any of these fans can be operated as needed. Butterfly dampers adjacent to each of these cooling fans are adjusted to maintain a balanced flow of the atmosphere gas, most of which is introduced near the middle of the heating zone.

The furnace has an effective width of about 34 in. and a maximum operating temperature of 1700° F. Automatic three-zone control of the heating chamber assists in maintaining a high degree of temperature uniformity.

Fig. 3—Power-Driven Coilers at Discharge End of Bright Annealing Furnace at Huntington Works, International Nickel Co. Strip is interleaved with paper to avoid scratching during subsequent handling



Work Hardened Surfaces of Fatigue Specimens

By Frederick C. Hull
and H. R. Welton
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East Pittsburgh, Pa.

IT HAS BEEN KNOWN qualitatively for some time that machining and polishing deform and work harden the surface layer of a metal. In a bending-fatigue specimen, this effect is important because the surface is the most highly stressed region and is the place where failure begins. In notched fatigue specimens, the importance is accentuated because of the stress concentration factor at the base of the machined notch.

Variable results in fatigue testing may have been caused by differences in specimen preparation and hence differences in surface work hardening. It was, therefore, decided that measurements should be made of the depth of penetration of cold work by machining, such measurements to serve as a guide in setting up specifications for the preparation of fatigue specimens.

The depth of penetration of the cold worked layer caused by machining may be measured in at least three ways:

1. T. Digges ground a taper along his specimens of carbon and alloy steel and measured diamond pyramid hardness with a 10-kg. load to find the depth at which the material was no longer hardened by surface working.

2. Thomassen and McCutcheon used X-rays to gage the depth of cold working of brass by machining. They etched away surface material until the diffraction patterns no longer showed wide lines, evidence of distorted crystals.

3. The present writer had already studied the surface effects of grinding and polishing by testing such surfaces with Tukon and Vickers hardness machines. Impressions were made with increasing loads until the hardness became constant. The depth of impression at which the hardness levels off was taken as a measure of the depth of work hardening.

This third procedure probably yields a greater depth than other methods, but since the result is on the safe side (at least as far as getting a good fatigue specimen is concerned) this may actually be an advantage. This plan was followed in the present investigation.

Two disks, ½ in. thick, were cut from a fatigue specimen of normalized S.A.E. 1020 steel, ground flat on one surface, and the other side planed. Specimen A was reduced to ¼-in. thickness with cuts each of 20-mil (0.020-in.) depth. Specimen B had a series of finishing cuts, respectively 10, 7, 4, 2 and 2 mils each.

To prepare the machined surfaces of these specimens for hardness tests, the deep gouges from machining were removed by hand polishing on emery paper. Just enough material was removed to get below the deepest tool marks. Specimen A, which had been machined with 20-mil cuts, cleaned up within a depth of 1.8 mils. Specimen B, whose finishing cuts were not as deep, cleaned up when 1.1 mils were removed. After this operation (with No. 1 paper) a metallographic polish was secured by subsequent work with No. 0, 00, and 000 papers, finally finishing by holding 3 min. on a wax wheel impregnated with 600-mesh alundum, and 3 min. on Selvyt cloth using Fisher No. 3 alumina.

Eight hardness tests were made on the prepared surfaces with the Tukon tester for each load of 100, 200, 400, 900 and 1900 g. and with the Vickers tester using loads of 2½, 5, 10, 20, 50 and 100 kg. The Knoop impression for a load of 100 g. (0.084 mm.) corresponded closely to the size of the areas of ferrite and pearlite in the

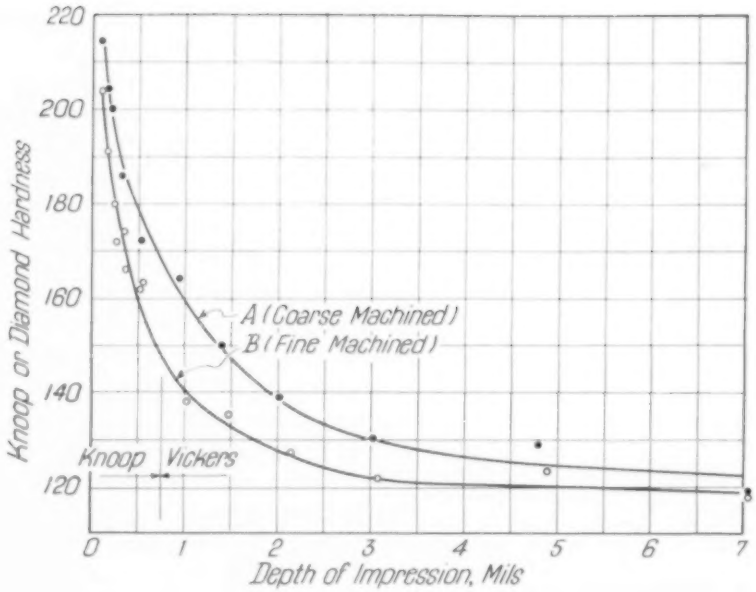
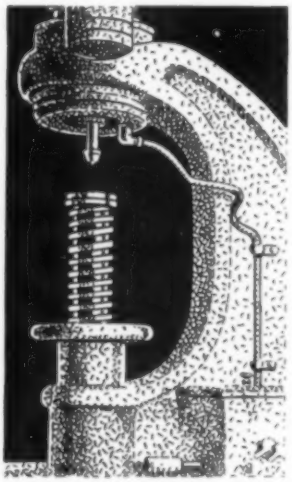


Fig. 1 — Hardness Versus Depth of Impression Below Polished Surface of S.A.E. 1020, Planed With Coarse Cuts (Specimen A) and Finished With Fine Cuts (Specimen B)

normalized steel. The individual hardness readings at the lightest load on Specimen B, for example, were found to vary considerably — from 178 to 252 — but it is thought that the average of the eight readings (204) is fairly representative.

Results are plotted in Fig. 1, representing hardness versus depth of impression below the polished surface. These results indicate that coarse machining affects the material to a somewhat greater depth than finer cuts, but even the latter work hardens the steel to a depth of several mils. An increase in hardness of 80 points, from about 120 for the undisturbed steel to 200+ for the machined surface, represents a considerable degree of deformation and proves that methods of preparation of fatigue specimens have not been sufficiently exacting. (The procedure has been to take fine finishing cuts on the lathe and then polish the surface with emery papers only to the point of removing the tool marks and paper scratches.)



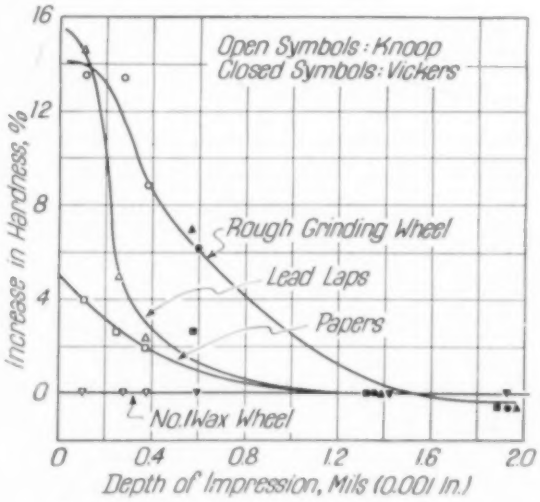


Fig. 2 — Depth of Work Hardening Resulting From Metallographic Polishing of 70:30 Brass; Initially 157 Diamond Pyramid Hardness, 10 Kg. Load

Figure 1 shows that prolonged polishing is required to get below the metal work hardened by the lathe tool. Approximately 5 mils should be taken off the final machined surface of Specimen A and 3 mils off the surface of Specimen B to get below the effects of appreciable surface deformation and hardening.

Previous work had shown that metallographic polishing causes slight work hardening, but — compared to the effect of machining — of negligible depth and amount. Figure 2 indicates that hand polishing of 70:30 brass increased its hardness 5% to 165 KHN at the very surface, and the increase was less than 3 points Knoop at a depth of 0.5 mil. In contrast with this, the hardness increases by machining are of the order of 50 points Knoop on a material of comparable hardness.

Thus, the effects observed and plotted in Fig. 1 are the result of machining and not of polishing. On the basis of these conclusions, therefore, a recommended specification for the finishing of fatigue test specimens would be:

1. Remove successive lathe cuts (on the radius) of 20, 10, 7, 4, 3 and 2 mils.
2. Remove at least 2 mils by polishing with Armour's alundum abrasive grade 150.
3. Remove 2 mils by polishing with Behr-Manning emery paper, grit No. 1.
4. Polish successively on emery papers No. 0, 00, and 000 twice as long as it takes to remove the scratches from the preceding paper. (The material removed by these three fine polishing papers should amount to a total of about 0.5 mil.)

By Our Special Correspondent

Hardenability and Its Estimation

CURRENT interest of metallurgists in the subject of hardenability of steel was evidenced by the symposium held by the Iron & Steel Division of the American Institute of Mining and Metallurgical Engineers in New York City on October 25. This symposium, under the chairmanship of C. M. Loeb, Jr. of Climax Molybdenum Co. and Irvin R. Kramer of the Naval Research Laboratory, included eight papers by some of the most important contributors in this field. The meeting opened with introductory remarks by M. A. Grossmann, director of research of Carnegie-Illinois Steel Corp. and past-president ⊖, who pointed out that much of the difference of opinion and practice concerning hardenability and its estimation arises from its as yet empirical nature, and from the lack of sufficient suitable data. He emphasized that the present interest should bring about a more fundamental system for computing hardenability from composition. He touched upon the uncertainties in such a computation arising from lack of solution of carbides in the steel during its preliminary heating, and from failure to analyze for those residual elements which may have considerable effect.

Seven of the eight papers presented during the day dealt with the factor method of calculating the hardenability of steel from chemical composition, originated by Dr. Grossmann in 1942. The papers divided themselves into several groups. Three papers were contributions of new data concerning the factors for the effects of various elements upon hardenability. I. R. Kramer, Sidney Siegel, and J. G. Brooks described a continuation of the experimental work by the group at the Naval Research Laboratory, and they pointed out that the factor used by Grossmann for the influence of carbon on the hardenability of iron-carbon alloys rested upon a somewhat insecure basis. If the factor for carbon were incorrect, then the manganese and silicon factors, which are necessarily based upon the iron-carbon factor, would also be incorrect. These three investigators measured the hardenability of a large number of steels by hardness surveys of Jominy end-quench specimens. They found the iron-carbon factor to be three times as great as Grossmann's, and that consequently the effects of manganese and silicon were less than Grossmann had predicted. Another interesting point developed from the data from the Naval Research Laboratory, which seemed to indicate that the linear relation between the effect of each alloying element and the percentage of the element, reported in the early work, was only a first approximation, and that actually the multiplying factors for the various elements increase more rapidly than the percentage of the elements increases.

In commenting on this paper Dr. Grossmann confirmed the larger iron-carbon factor reported by the authors, although he did not agree that the difference between the actual hardenability of iron-carbon alloys and his original estimate was as large as a factor of three. This discrepancy as to the effect of carbon does not in general invalidate computations for most medium alloy steels, based on Grossmann's early figures and such presentations of them as contained in *Metal Progress* Data Sheet No. 29 and the tables computed by Joseph Field of Bethlehem Steel Co., because the combined effects of carbon, manganese, and silicon in the normal ranges are the same whether the new data or the old data are used. However, for very small or very large contents of these elements the two sets of factors will give widely different results.

The next matter of a rather unsettling nature came from data obtained by G. R. Brophy and A. J. Miller of the International Nickel Co., which appeared to contradict Grossmann's fundamental assumption of the multiplicative character of the effects of alloying elements! These investigators

found that nickel, for example, has a greater multiplicative effect in high manganese steels than in low manganese steels, and in high chromium steels than in low chromium steels. It was pointed out in the discussion, however, that a small experimental error would resolve the data so that they would fit the multiplicative system. In fact, Walter Crafts showed graphs, using modified Grossmann factors, which indicated that the data of Brophy and Miller were not inconsistent with the multiplying principle. Grossmann emphasized that these inharmonious data and their variable interpretation illustrated the difficulties in the experimental study of hardenability.

G. F. Comstock of the Titanium Alloy Mfg. Co. presented a paper which cleared some of the existing confusion as to the effect of titanium upon hardenability. He correlated the multiplying factor for titanium with the titanium *in solution* in the austenite, rather than the total titanium. (Separation of the soluble titanium from the insoluble titanium was done by chemical methods.) Furthermore, he found that the carbon tied up with the titanium as insoluble carbide should be subtracted from the composition, if close correlations between hardenability and composition are to be obtained. Comstock further showed the relations between austenitizing temperature and hardenability when they are influenced by the solution of titanium carbide.

Partially Martensitic Structures

The second group of papers related to more general considerations of hardenability than did the first group. Further work from the Carnegie-Illinois Steel Corp. pointed out the importance of the criterion that was used to measure the hardenability. By microscopic examination of quenched Jominy bars, J. M. Hodge and M. A. Orehoski determined the relations between the Jominy distance for 50% martensite and the distances for various other percentages of martensite. They found that the Jominy distance at which steel fully hardened to 100% martensite was considerably less than the distance at which it hardened to 50% martensite. Thus, if parts are to be fully quenched to martensite, considerably more hardenability is required than when only 50% of martensite is desired. (Grossmann originally utilized the 50% criterion because the point at which it occurred was easy to measure with accuracy.)

The paper of Hodge and Orehoski also included the first quantitative determination of the relations between hardness and per cent of martensite (in the Jominy test bar) for steels of various carbon contents. The relations developed by the authors referred primarily to steels in which the non-martensitic product was bainite and not pearlite. They found out that, when hardenability was calculated by the Grossmann method for the steels they studied, considerable divergence was obtained between the calculated and the measured hardenabilities for a microstructure containing 50% martensite. This difference was attributed to lack of solution of carbides, since the calculated hardenability was much larger than the measured hardenability. H. W. Gillett of the Battelle Memorial Institute, in written discussion, pointed out the importance of full hardening to the attainment of optimum mechanical properties and congratulated the authors on their paper which recognizes this fact.

J. H. Hollomon and L. D. Jaffe of the Watertown Arsenal Laboratory attributed to a more fundamental cause this difference in hardenability to produce a half martensitic or a fully martensitic structure. They pointed out that when the structure is 50% martensite in plain carbon steels, pearlite makes up the other half of the structure. In some more complex steels, however, particularly those containing large amounts of molybdenum, the presence of acicular bainite rather than fine pearlite limits the hardenability. As alloying elements have different effects upon the reactions within the austenite which produce pearlite and bainite respectively, a dual concept of hardenability was thus suggested:

Instead of defining hardenability in terms of the effects of alloying elements on the cooling rate at which martensite *forms*, Hollomon and Jaffe define it in terms of the cooling rate necessary to *avoid* either the pearlite or the bainite reaction. Such a definition involves two hardenabilities, the pearlitic and the bainitic. The authors of this paper pointed out that Grossmann, as well as subsequent investigators of hardenability, usually measured the effects of alloying elements on the pearlitic hardenability — that is to say, their effects on the retardation of pearlite formation during continuous cooling.

Hollomon and Jaffe then gave an approximate method for calculating the bainitic hardenability, derived from studies of isothermal measurements of austenite decomposition. In their system molybdenum appears to have little effect upon the retardation of the bainite reaction, although it does have a large effect in retarding the pearlite reaction. If the molybdenum is added to plain carbon steels the hardenability will first increase very rapidly, since pearlite limits the formation of martensite, and thereafter will have a very small effect, as bainite begins to limit

formation of martensite. This "fading" in the effects of molybdenum and chromium has been observed by many investigators.

In attempting to check the predictions based upon isothermal measurements, Hollomon and Jaffe found that, whereas grain size has no effect on the bainite reactions as measured isothermally, increasing the grain size increases the bainitic hardenability. This they interpreted as an incubation effect, involving nucleation of the bainite reaction by ferrite which formed in the temperature range of pearlite transformation. This dependence of the bainitic hardenability upon the pearlitic will be a complicating factor in establishing the ultimate hardenability system.

In another paper, these same authors discussed the relation of hardenability to quenching cracks. They suggested that since a low temperature for martensite transformation certainly leads to an increased tendency toward quenching cracks, it would be desirable to obtain the desired hardenability from compositions having the highest martensite transformation range.

From the available data Jaffe and Hollomon were able to establish a method wherein combinations of alloying elements could be determined to give the desired hardenability with the maximum temperature for the start of martensite formation. In the discussion, Cyril Wells emphasized that not only composition but also seams, flakes, inclusions, and other defects affect the susceptibility of a steel to quench-cracking, for a given quenching practice.

Best Hardenability for Least Cost

This same principle of obtaining an optimum combination of elements was applied to the problem of *cost* of alloy steels by H. E. Hostetter of the Climax Molybdenum Co. Instead of maximizing the Ms or martensite start temperature to obtain minimum quench-cracking, he determined the combinations of alloying elements that provide a given hardenability at minimum cost. Essentially the same method of computing the proper combination for minimum cost was used which Jaffe and Hollomon used in assessing the combination that will lead to minimum quenching cracks. These papers illustrate the extreme importance of determining the proper multiplying factors for formulae assessing the influence of the various elements. The alloy combinations that are cheapest and cause the least trouble in heat treating for a fixed hardenability are greatly affected by the hardenability factors. Small changes in these factors lead to radically different optimum alloy combinations.

In the one paper that did not deal with the Grossmann system, Walter Crafts and J. J. Lamont of Union Carbide and Carbon Research Laboratories reported the results of their continuing study of hardenability and of the effects of alloying elements upon it. A large number of Jominy data from various steels were analyzed by these authors, and a simple additive method of evaluating the effects of alloying elements was developed for predicting the Jominy hardness curve from the steel's chemical composition. This system of calculation is wholly independent of the Grossmann method and, like it, is completely empirical. Crafts and Lamont's method seems to be able to calculate Jominy hardenability curves to ± 6 points on the Rockwell C scale. This spread results partly from the error in hardness measurements and partly from actual differences between observed and calculated hardness. The authors' method of calculation thus gives only a fairly rough estimate of the hardenability of steels in terms of hardness.

In conclusion, it must be recorded that the general tenor of the symposium was more of discussion than of agreement; it was one of contradiction rather than of concord. As Grossmann suggested, part of this lack of agreement is due to inadequate data and incomplete experiments, while another cause is the lack of any theoretical or logical justification for the systems of computing hardenability from composition. This lack of theoretical justification requires the data to be treated statistically and does not permit interpolation and extrapolation after the establishment of a few critical experimental points.

A complete and adequate hardenability system must recognize that what is actually being measured is the retardation of the pearlite and bainite reactions. The final system must also be based upon a thorough understanding of how the alloying elements retard these reactions. Therefore such a system can be evolved only after the decomposition of austenite and the effects of alloying elements upon this reaction are pretty thoroughly understood. Decomposition on continuous cooling as studied by Liedholm*, for example, rather than decomposition at constant temperature, is pertinent here.

The matter is of far more than academic interest, for an accurate hardenability system will permit the metallurgist to choose a steel of minimum cost and the minimum tendency toward fabrication difficulties, such as quench-cracking, while it still has the desired hardenability.

*See *Metal Progress*, January, 1944, page 94, and data sheets for June, September, November, 1944 and October, 1945.

By Herbert Van Sciver
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Effect of Three Variables in Spot-Welding

RESISTANCE SPOT-WELDING is seldom completely understood because it is difficult to think clearly in terms of several variables simultaneously. Whatever approach is made, whether it be of a purely physical nature taking into consideration the problems of the heat flow involved in welding, or from a practical attitude considering only those quantities affecting the weld externally, a clear picture is not often forthcoming.

In an effort to help clarify this picture from the practical side, several series of welds have been made in the Budd Laboratories under carefully controlled conditions. In each series, all the variables under our control were held constant except one which was varied between limits, and its effect on the weld strength and formation noted. The variables under control were current, time, tip force, and electrode shape. Of these, all except electrode shape were varied one at a time.

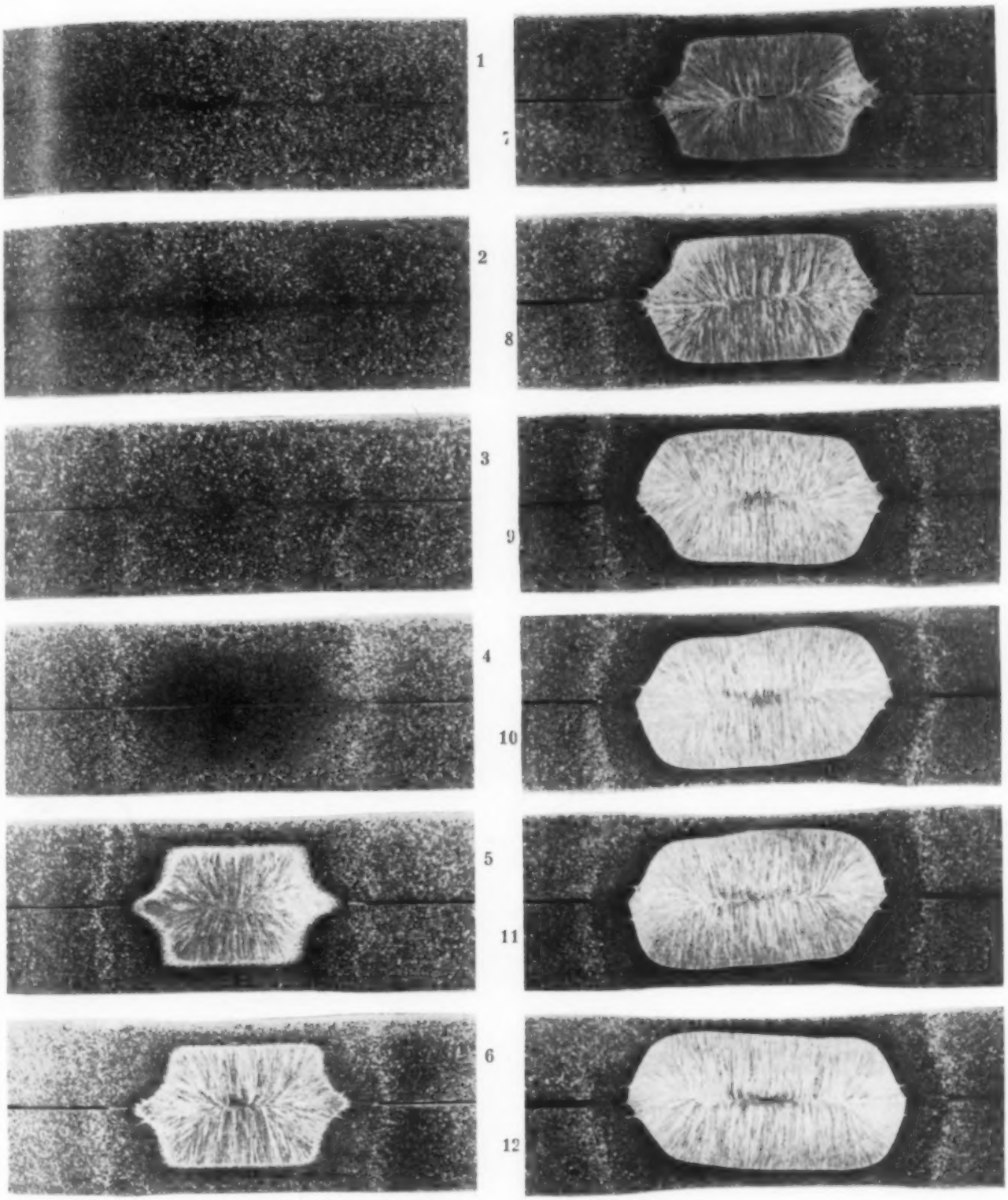
High tensile stainless steel (18-8) sheet 0.075 in. thick was chosen for this demonstration since the quantities affecting the weld are of such magnitude as to be easily varied. The current, time, tip force, and electrode shape, were arranged — drawing on former experience with the metal — so as to give a 4600-lb. shear weld when using 8900 amperes in 12 cycles (0.20 sec.), at a tip force of 1900 lb., with tips dressed to 2½-in. radius, ⅝-in. diameter.

In the first series (etched cross-sections of spots shown on the next page) the time was varied, cycle by cycle, to show not only the effect of time on weld strength, but also to demonstrate the evolution of a normal weld. It is interesting to note that the growth of the weld is a direct function of time, once the weld has been formed. At the current density used it took four cycles to bring the weld zone up to fusion temperature and to supply the heat of fusion. (At higher currents this would occur earlier, and at lower currents it would occur later.) It is also interesting that little or no forging took place before actual fusion. The unfused sections have some strength due to "plastic fusion", but they are brittle bonds and are unreliable in stainless steel.

In the second series, time and tip force were held constant at 12 cycles and 1900 lb. respectively, while the current was varied from 3100 amperes to 11,800 amperes, a current of 8900 amperes yielding the weld which was used as standard of comparison. Apparently a balance between heat input and heat loss is set up, or nearly so, in 0.075-in. stainless steel in 12 cycles, since there is no condition of stopping just short of a weld in this series as there was in the time series. (The uniform and symmetrical shape of the welds bear this out. Note the difference in shape between these and those in the time series.) It will be noticed that weld diameter and weld strength are a direct function of current, 4100 amperes producing the first real fusion and 11,800 amperes expelling metal under these conditions.

The presence of cavities in some of the welds and not in others in these series should not be taken as evidence that certain conditions are superior to others in producing sound welds. X-ray examination of these welds showed that all of the larger ones possessed cavities, but they did not all occur in the center of the weld through which the section was taken.

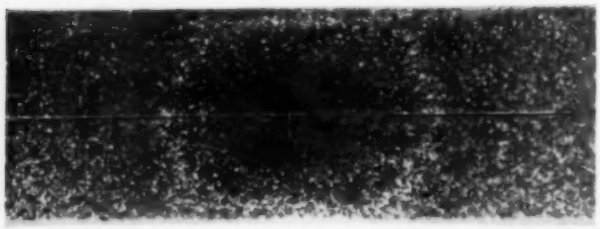
The third series shows the effect of varying tip force while holding current and time constant. Since the contact resistance between two relatively smooth, clean surfaces is an inverse function of the force applied to them, and the heat evolved by passing a current through this resistance for a given time is equal to the product of the current squared, the resistance, and the time.



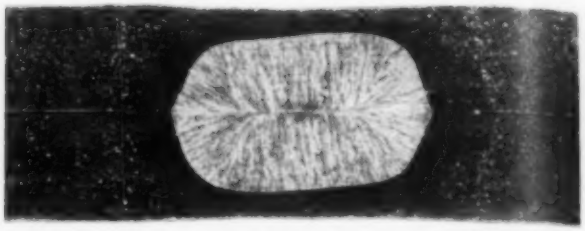
Time Study (1 to 12 Cycles)

1900-lb. tip force; 8900 amp.; tips ⅝ in. diameter and 2½ in. radius

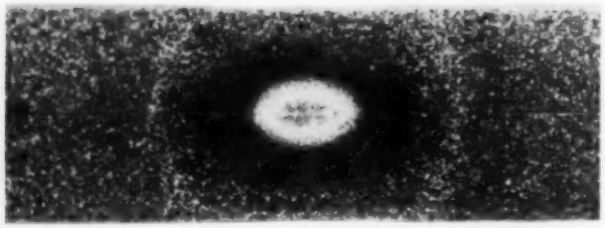
Text continued on page 1295



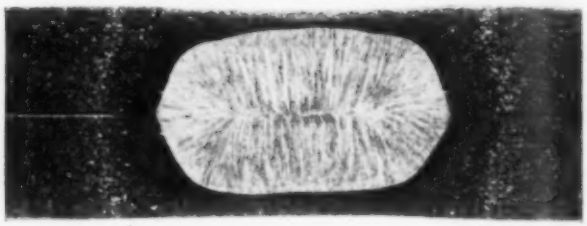
3100 amp. pull 0 lb.



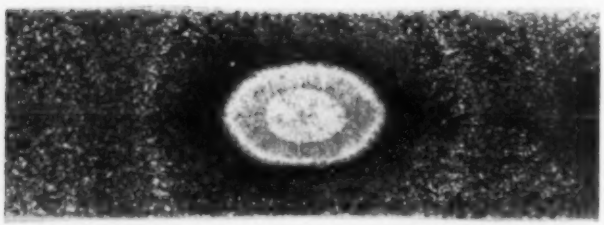
7100 amp. pull 3700 lb.



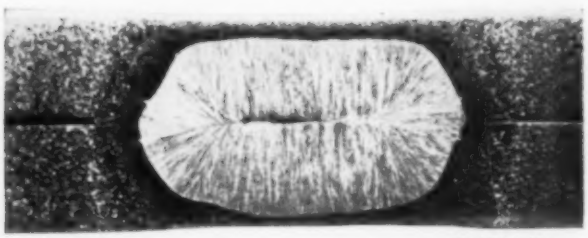
4100 amp. pull 700 lb.



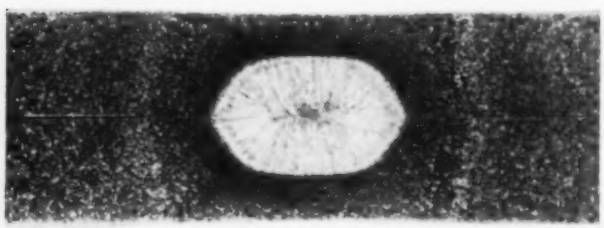
7900 amp. pull 4200 lb.



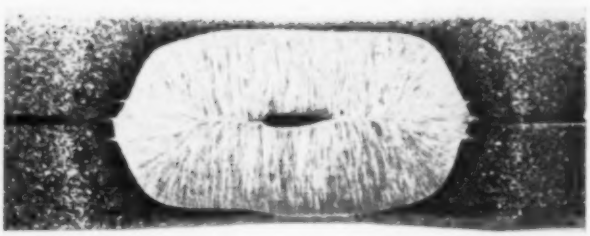
4700 amp. pull 1350 lb.



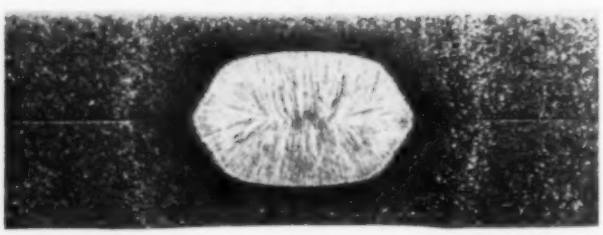
8900 amp. pull 4600 lb.



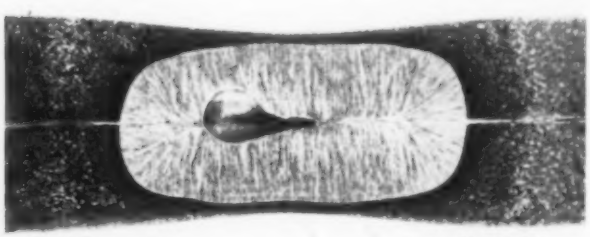
5200 amp. pull 2000 lb.



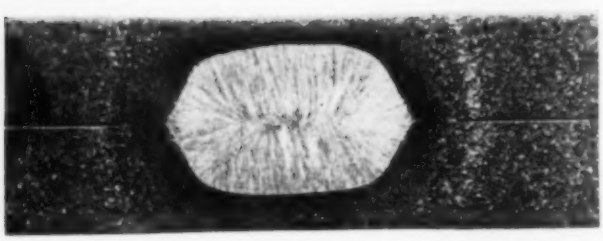
9900 amp. pull 4900 lb.



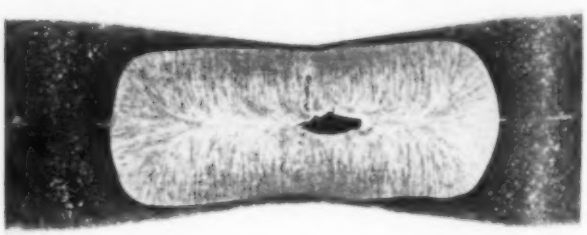
5900 amp. pull 2600 lb.



10,600 amp. pull 5000 lb.



6400 amp. pull 3200 lb.



11,800 amp. pull 4500 lb.

Current Study (3100 to 11,800 Amperes)

1900-lb. tip force; 12 cycles; tips ⅝ in. diameter and 2½ in. radius

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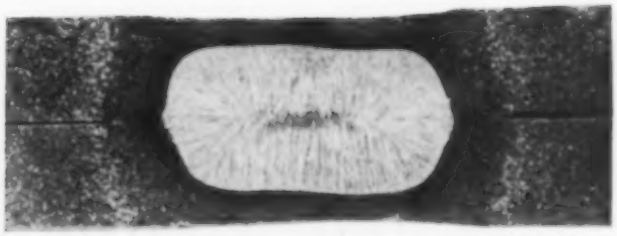
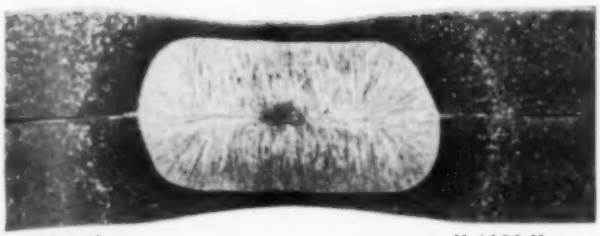
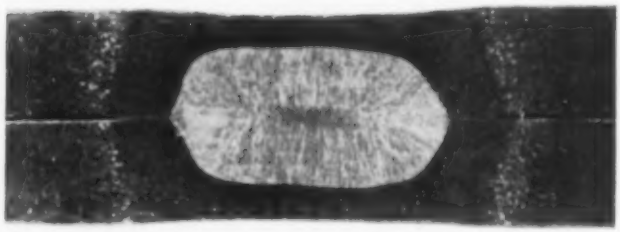
1060 lb. pull 3000 lb.



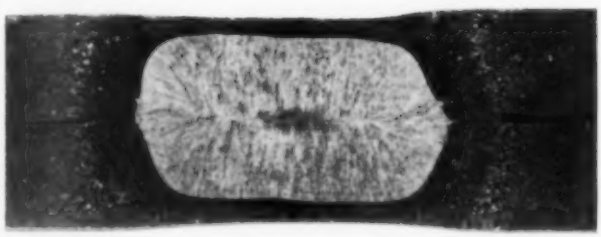
2760 lb. pull 3770 lb.



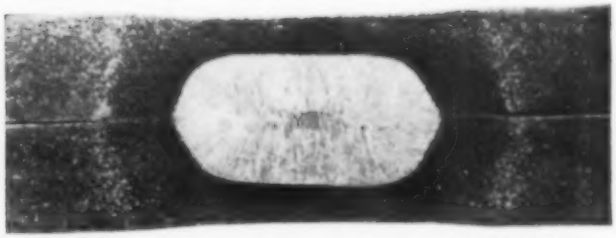
1500 lb. pull 4100 lb.



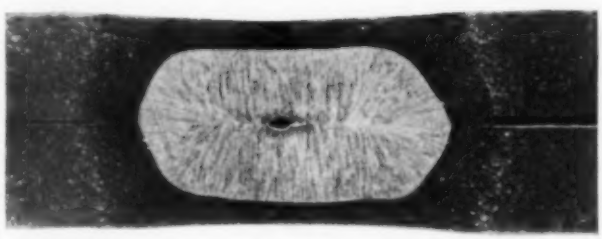
3180 lb. pull 3450 lb.



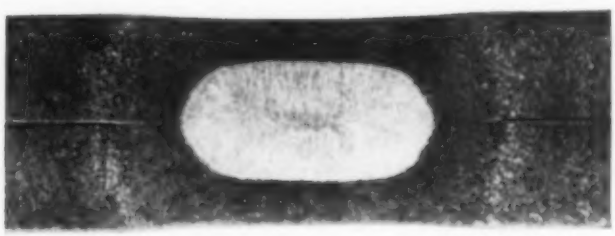
1900 lb. pull 4600 lb.



3600 lb. pull 3270 lb.



2340 lb. pull 4370 lb.



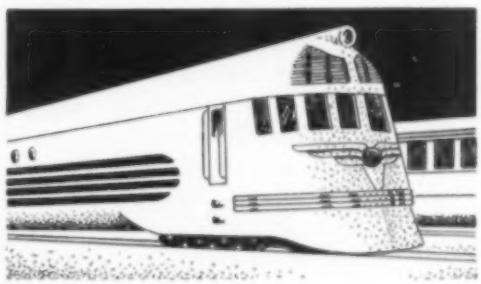
4000 lb. pull 3040 lb.

Tip Force Study (1060 to 4000 lb.) of the Formation of a Spot-Weld in 0.075-in. Stainless Steel Sheet

8900 amp.; 12 cycles; tips ⅝ in. diameter and 2½ in. radius

it is evident that the weld development is an inverse function of tip force. The force was varied from 1060 to 4000 lb. in this series. Welds made at the two lowest forces developed so much heat that metal was expelled. This expulsion of metal has some effect of arresting the development of weld diameter, and consequently strength, which accounts for the lower strengths of these welds despite the greater heat evolved. As the tip force increased above the normal 1900 lb. the dropping off of weld size and strength is very apparent.

The use of these charts has proved very helpful in explaining the functions of these three variables to persons unacquainted with resistance spot-welding. They have become especially useful when the specific values are ignored, and the charts used to explain trends in weld development rather than to attempt to use them as data sheets.



By Conrad C. Wissmann
SF 3/C
Construction Battalion
U. S. Navy

Final Additions to an Acid Electric Heat

THREE ARTICLES by the present author have been printed in *Metal Progress* for October 1944, December 1944 and September 1945 discussing in shop terms the problems of furnace maintenance, charging and working a heat, and deoxidizing a heat of acid electric steel. I will now attempt to outline a good practice for meeting the required chemical specification, and the reasons for some of the important recommendations.

A melter, besides producing clean and sound steel, must adjust its chemical composition to meet the demands of the consumer. Today when alloy steels are coming more and more into use, this becomes an increasingly difficult job. Customers are more and more specific in their demands for metal of a very definite chemical composition. It is not at all uncommon for him to specify that the carbon content of the steel be within two points, or that the manganese content be within a certain ten-point range. This article will express the author's opinions as to the best time during a heat when the different alloys should be added to steel.

Fortunately for the melter, three of the alloys which are commonly used in steel can be added at any time without loss to the slag during the steelmaking process. These three alloys are copper, nickel and molybdenum. Copper is usually added to the furnace with the charge, as it is then most convenient. Nickel can be added with the charge or thrown into the furnace as soon as a pool is formed. Molybdenum, since this element is usually added as calcium molybdate or molybdic oxide, can also be added with the charge or thrown into the furnace as soon as a pool is formed. If they are not put in with the cold charge these three alloys should be added from 15 to 30 min. before the heat is tapped, as may be convenient. This will give more than ample time for their solution and distribution throughout the metal.

Silicon is usually charged as 50% ferrosilicon, an alloy containing approximately 50% iron and 50% silicon. Usually electric furnace melters figure that there is no loss of silicon added to the furnace, when the heat is boiled, deoxidized, and the temperature and slag controlled in a satisfactory manner. However, if the preferred conditions do not exist in the furnace, there is certain to be a considerable loss of silicon to the slag, up to an extreme of half of the amount added. Silicon control, therefore, depends on its practically complete recovery, and this in turn requires that working and deoxidizing be properly done.

Enough silicon is added to steel which is used for castings to give the metal at least 0.30% (preferably 0.40%). Although this alloy very readily reacts with oxygen in the steel, there is not usually a very great loss of ferrosilicon, for the slag over the metal at the final stages of the heat when the alloy is added is already composed primarily of silicon dioxide. Therefore, it has little ability to pick up more of this oxide from the metal.

Manganese is usually added as the alloy known as ferromanganese. The common grade contains approximately 80% manganese, 13% iron and 7% carbon. This alloy is usually added to the furnace just before the steel is tapped. The oxide which it forms in the metal, manganese oxide, is basic and is very readily picked up by the acid slag (that is, the slag high in SiO_2). Therefore, the longer it is held under this slag before tapping, the greater will be the loss.

If a steel is to have over 1% manganese, it is usually best to add three-quarters of it in the furnace and the balance in the ladle.

It is not uncommon for the manganese content to gradually decrease even after the heat is tapped into the ladle, as the steel is being poured.

Of course, the better deoxidized the steel before the manganese addition, the less will be the loss, for the manganese will find no oxygen in the metal with which to react. If a manganese content of 0.80% or less is desired, a 15% excess over the amount of manganese necessary to raise the content to the desired figure is usually added to the furnace. If the manganese content must range from 0.80 to 1.50%, the loss of manganese will vary from one-quarter to one-third. If an even higher manganese is ordered, the loss will sometimes be as high as one-half.

When the manganese content of the steel is raised to over 1.25%, it is very difficult to hold it in the metal under an acid slag. Sometimes it is good practice to lime the slag before the steel is tapped, decreasing the acidity of the slag and therefore decreasing its ability to absorb manganese oxide.

It is to be remembered that when manganese is added to steel it will also raise the carbon content of the steel, since the ferromanganese contains 7% carbon. To compensate for this, the steel is usually boiled until the carbon has been reduced to a sufficient degree below that which is necessary in the finished steel.

Chromium is usually added to the bath after it has been deoxidized (that is, just after the final silicon addition) usually as ferrochromium. This alloy contains approximately 68% chromium, 6% carbon and the balance iron. The loss of chromium from the steel is not quite as great as manganese. However, in adding it to steel, the same rules are usually followed as adding the same amount of manganese. Addition of chromium will also raise the carbon content of the metal, unless some of the low carbon grades of ferrochromium are used.

To bring a soft heat up to specification, carbon is usually added to the furnace as pig iron, which contains a known amount of carbon, usually in the neighborhood of 3.50%. However, there are times when it is better to dip the electrodes down into the bath and let the steel dissolve carbon from them. If this is done there is always a furious boiling action around the electrodes. This boiling action decreases the oxygen content of the bath — that is, deoxidizes it — and therefore many melters will prefer to carbon-up an over-oxidized heat with the electrodes.

Alloys such as aluminum, titanium, zirconium, vanadium and boron are added in the ladle. They are highly reactive and if added in the furnace they would be quickly taken up by the slag. The common method is to place these alloys in a paper sack and throw it into the ladle while the steel is being tapped so that the sack hits the metal stream. The downward rush of liquid will carry these alloys through any slag into the metal where they are very readily dissolved, and uniformly mixed.

It is most important that the melter have a rough idea about the analysis of the heat during any stage — that is, what the carbon, manganese and silicon will be, and how they will change as the heat progresses. Variation in the chemical composition of a typical heat is plotted in Fig. 10, taken from John Juppenlatz's paper on "Acid Electric Furnace Slag Control" read before the American Foundrymen's Association at the 1942 convention.

As can be seen from the graph, the manganese and silicon content of the metal will decrease

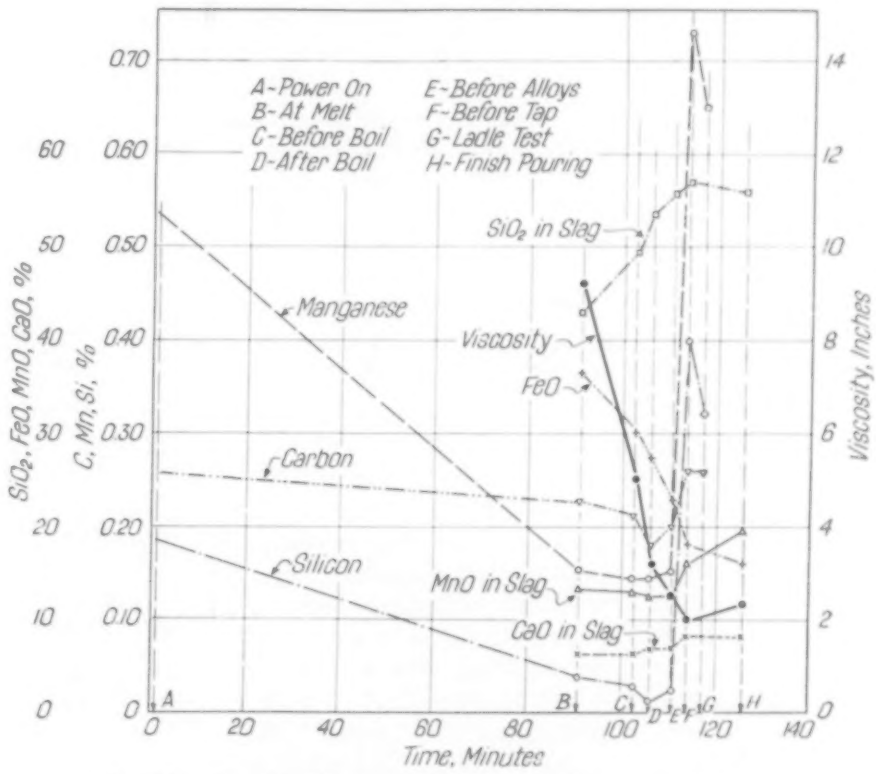


Fig. 10 — Graphical Representation of the Changes in Chemical Composition of the Bath and the Slag Viscosity During the Course of a 4-Ton Heat of Carbon Steel. (Juppenlatz)

as the heat progresses, reaching the lowest point at the start of the boil. This is easy to understand, in the light of what has been said in former articles of this series, since they are continually being oxidized out of the metal and rising up into the slag during the early stages of the heat. The carbon however does not decrease to any large extent until a certain temperature has been reached, whereupon the boil starts; then it decreases rapidly until the boil stops. As was pointed out in former articles, if a melter knows the carbon content of the heat at any time during the boil, he has an idea as to the amount of silicon and manganese left in the steel, since they will be roughly proportional to the carbon content. (The manganese content during the boil will be a little less than two-thirds of the carbon content.) During the boil the silicon will go down to a very low figure, and then gradually increase until at the end of the boil it will be somewhere between 0.05 to 0.10% (depending on melt-down conditions, nature of scrap, the condition of the furnace lining, and such variables that make steelmaking as much an art as a science). The manganese content of the metal will also increase slightly as the steel becomes more and more deoxidized during the boil.

This ratio between the carbon, manganese and the silicon content almost always holds true. However, if the scrap charged in the furnace is very high in manganese — which happens but rarely — then the manganese content in the steel will be higher than usual, due to an excess of manganese in the slag. The important thing is to remember this interrelation between carbon, silicon and manganese during the boil; it is doubly important if you want to hit the manganese specification closely, for if the boil has reduced the carbon to a very low amount, then the manganese will also have been reduced to a low amount. Therefore, additional manganese must be added to such a heat to compensate.

Ladle Additions

Final deoxidizers are usually added to the ladle. There are a good many of them available — aluminum, zirconium, calcium, titanium, vanadium and boron. The most commonly used is aluminum in shot form. Usually it is placed in a paper sack and thrown into the stream of metal as the heat is being tapped.

The amount of aluminum has a great effect on the physical properties of the steel to which it is added. If less than 0.5 lb. of aluminum per ton of steel is added, the physical properties will be good. Likewise, if 2 lb. of aluminum per ton are added, the physical properties of the steel will be good. However, an intermediate amount of aluminum, usually about 1.0 lb. per ton, will form intergranular inclusions of a stringy nature, which will very adversely affect the physical properties of the steel.

A good deal of research has been done on this subject, and since the information is readily available, I will only mention the matter, and raise a warning signal. Aluminum is a very valuable reagent in steel making, *when it is used intelligently*. Some important articles which have appeared on this subject are listed in the footnote, and for a more detailed account, the reader should obtain these publications.*

Getting the aluminum into the bath presents some difficulties. Too often the sack of aluminum shot, when thrown into the ladle while the heat is being tapped, will not get past the slag — or, what is worse, only a part of the amount thrown into the ladle will get into the steel. Too often, when 2.0 lb. per ton are added, only about half of it actually gets into the steel, and this will be just enough to produce the undesirable intergranular inclusions.

Therefore, the safest method of adding aluminum is in the hand shanks or small ladles, a weighed amount being added to each small pot. When the steel is poured from the big ladle into the small ladle, there is no danger of the aluminum becoming trapped in the slag, for no slag goes with the metal. Another method used by some shops is to tie aluminum bars on the end of a long steel rod and plunge the steel rod through the slag at the top of the ladle into the steel, leaving it there long enough for the aluminum to melt.

It is the author's opinion that unless a method has been worked out satisfactorily in the shop that guarantees that all of the aluminum which is weighed up gets into the metal, it is better practice to add only 0.5 lb. of aluminum per ton and thus be on the safe side. However, in green sand castings there is little doubt but that consistently sounder castings will result if 2 lb. per ton or more are added. As can be seen from Fig. 6 in the September 1945 article, a very small amount of aluminum will almost

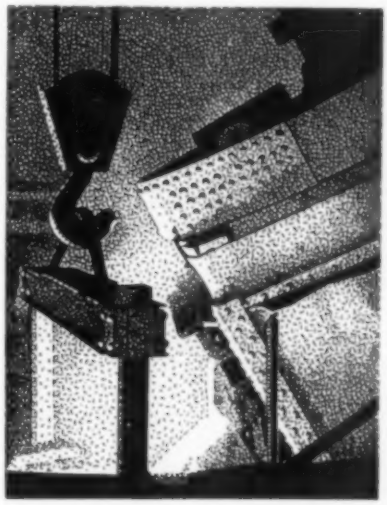
*"Effect of Aluminum on the Properties of Medium Carbon Cast Steel," C. E. Sims and F. B. Dahle, *Transactions of the American Foundrymen's Association*, v. 46, 1938, pp. 65-104.

"Formation of Inclusions in Steel Castings," Walter Crafts, John J. Egan, and W. D. Forgeng, Technical Publication No. 1184, American Institute of Mining and Metallurgical Engineers.

"Final Deoxidation for Cast Steel," Walter Crafts and John J. Egan, booklet by Electro Metallurgical Co., N. Y.

completely remove any FeO that was left after the silicon and manganese addition; therefore this small excess will insure a sound casting.

If a great many shops which are consistently adding 2.0 lb. of aluminum per ton to their steel were to analyze several of their heats, they would be surprised to find that in many of them only a small portion of that aluminum actually got into the steel. I repeat, therefore, that it is very important, for any shop which intends to add this much to the steel, to work out a more satisfactory method than just throwing a bag of shot into the stream of steel coming from the furnace.



It may seem to the reader that the author is prejudiced in favor of the one smallest addition of aluminum to steel. This is not so. However, the problem of getting *all* of it into the steel is one which melters often treat too lightly.

It should also be mentioned that the sulphur content of the steel has a great deal to do with the degree to which a critical amount of aluminum can adversely affect the physical properties of the steel, since the intergranular inclusions found in such steels are sulphides. If the sulphur content is low, say 0.03% or even lower, the ductility of the steel will not be lowered as much as if the sulphur content is up to 0.05%. Melters who add the larger amount of aluminum in the ladle should remember this, and try to secure scrap with a low sulphur content.

It has been found that when a certain amount of calcium is added to the metal *with the aluminum* it tends to prevent the formation of the damaging inclusions. Calcium is usually added as a calcium-manganese-silicon alloy or a calcium-silicon alloy. The first analyzes approximately 18% calcium, 9% manganese, 58% silicon and 12% iron; the latter analyzes 30% calcium and 62% silicon. Many who have tried both think that the calcium-manganese-silicon alloy is the more effective. Best results will be obtained with this alloy when enough is added to represent a calcium addition of 0.05%, and the author is of the opinion that aluminum and calcium should always be used together. The inclusions then formed in the steel have a less stringy nature, and are less harmful than the ones described above. The use of calcium along with aluminum is not a cure-all but it does tend to prevent the formation of harmful inclusions.

There are a great many other ladle deoxidizers on the market. They contain various amounts of active oxygen scavengers such as zirconium, titanium, vanadium and boron. They are usually added along with aluminum, but their use is not very widespread. Zirconium is sometimes used in place of aluminum in steels where the sulphur content is high — that is, around 0.05%, and for the same reason as given above for the use of calcium.

The other three, titanium, vanadium and boron, also aid in the deoxidation of the steel, but are primarily added to increase its hardenability and produce a fine-grained steel. It is commonly known that the grain size of steel can be changed from a rather coarse grain to a fine grain by increasing the aluminum addition. Fine-grained steel is usually preferred for most purposes except for high temperature service. For this reason most metallurgists are agreed that steel should have enough aluminum added to it to make it fine grained. Fine-grained steels are somewhat tougher after heat treatment — that is, the impact strength (Izod or Charpy test) of the steel will be higher, and this property of resistance to shock is important in many, many uses.

Titanium, vanadium and boron, when added to steel in very minute amounts, are much more efficient in producing fine-grained steel than aluminum. Therefore, in steels which should have a high shock resistance, it would be wise to add them in the ladle along with the calcium and aluminum addition. However, to the author's knowledge it has not been shown that these alloys give much better tensile properties — that is, strength and ductility — than a steel which has been deoxidized in the ladle by the calcium and aluminum addition only, except possibly after a rather elaborate heat treatment of the finished casting.

The subject of ladle deoxidizers has been covered very briefly here, since the information as to their effect is readily available from companies which promote the various deoxidizers. However, this does not mean that the author considers this subject relatively unimportant. Too many heats have been spoiled by the improper amounts or improper method of addition. There is no other part of the process of steelmaking which is more important than this one.

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Manufacture of File Hard Precision Gears

AS RECENTLY as four years ago, if anyone had claimed to be manufacturing precision gears that would withstand files that are C-60 to 62 hard, he would have been greeted with a chorus of "It can't be done!" Even today, after several years of accelerated research and development of new and improved heat treating processes born of wartime necessity, there are many who find it hard to believe that "file-hard" gears (surface hardness C-60 to 61 Rockwell) have been and are being produced in large quantities for use in Allison V-1710 engines and the newer jet engines.

Early in 1941 we set out to furnish our heat treating department with the most modern and efficient equipment then available. Since then we have endeavored to keep abreast of all the latest developments of processes and equipment, so that at the present time we believe this department is second to none in the industry.

A general view of the department is shown in Fig. 1. With a capacity for handling all types of gears and other parts, and to operate on a 24-hr. schedule, the main heat treating area occupies approximately 18,000 sq.ft. of floor space, and has a full basement for the oil storage tanks and circulating system.

There are several rather interesting features not found in the usual heat treating department. Perhaps the most unusual is the fact that the entire area is air-conditioned. Another feature leading toward cleanliness and safety is the layout of the department which is designed for modified straight line production with parts moving on cranes, overhead and roller conveyers and traveling successively through degreasing, copper plating, carburizing, annealing, hardening, degreasing, tempering, shot blasting, and finally inspecting.

A centralized control room, with long lines of recording and controlling pyrometers, assures positive control of all furnace temperatures and

Fig. 1—General View of Allison Heat Treating Department With Carburizing and Annealing Furnaces in the Foreground. At left center may be seen the top of the centralized control room enclosure

the time cycles of quenching presses. Warning lights and a bell system are connected to notify the men at the carburizing furnaces.

Time standards on all of our heat treating operations, together with daily curves of case depths, data on re-works, scrap, and production, all contribute to a high level of efficiency.

Normalizing the Forging

Heat treatment of Allison aircraft engine gears is a very exacting process and warrants a step-by-step description.

With a few exceptions our gears are manufactured from AMS 6250 steel. This is "aircraft quality", carburizing grade (0.10% carbon), of 3½% nickel, 1½% chromium steel, No. 5 grain size or finer, and with maximum hardenability of C-41 $\frac{1}{16}$ in. from the end of the Jominy test bar, and minimum hardenability of C-32 at 6/16.

Critical gears are machined from forgings which require normalizing. This is necessary to form a microstructure and hardness that will facilitate the machining operations and relieve forging stresses. The work is done on trays in an electrically heated, pusher type of furnace with roller rail hearth and with controlled zone temperatures. The weight of the individual forging determines the tray capacity. There are three zones — a hot zone at 1750° F., the cooling zone which approximates an air quench, and the drawing zone. Temperature of the last mentioned is determined from hardenability tests, which are run on each heat of forging steel before acceptance. As noted above, furnace temperatures are regulated from the central control room. We have found that normalized hardness ranges of 217 to 255 Brinell for spur gears and 241 to 285 for bevel gears are most conducive to good machinability.

After normalizing, forgings are shot blasted, spot ground to remove forging decarburization, and Brinelled 100%, after which they are sent to the manufacturing area where the roughing operations are performed.

Rough blanks of all bevel gears and gears which are to be shaved are given further heat treatment at this stage to produce a very fine structure and hardness, and to minimize distortion in the final heat treating operations, as follows:

Blanks are racked on pins held vertically on carrier plates, pushed through a roller hearth furnace wherein they are heated to 1500° F. in a controlled atmosphere, and quenched automatically in a refined petroleum oil. Our gears of AMS 6250 steel give a Rockwell hardness of C-32 to 40 after this oil quench; after a 950 to 975° F. draw, the hardness averages C-28. Blanks are then shot blasted and Rockwell inspected 100%.

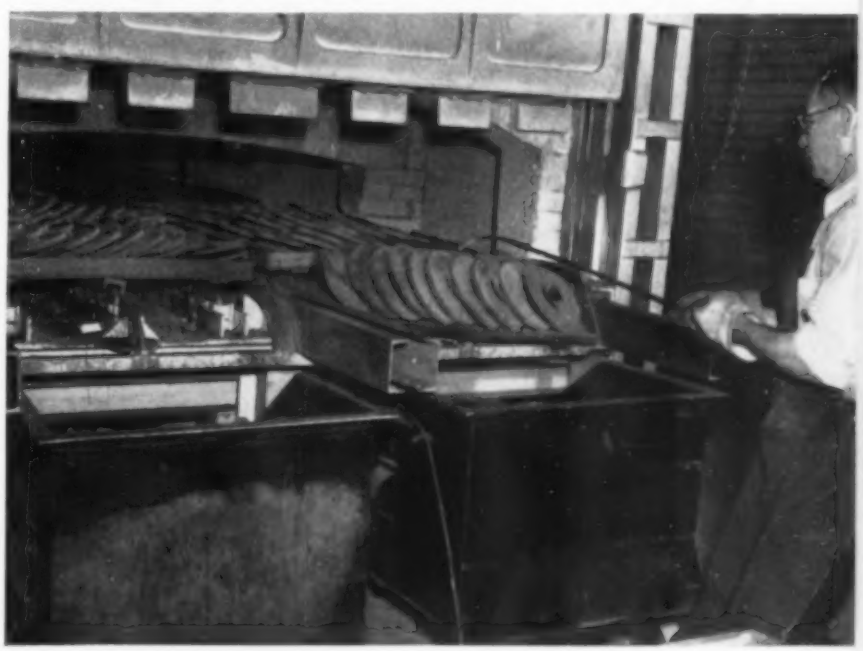
Copper Plating

In order to keep certain parts of the gears as soft as the core, or the core after it goes through the hardening processes (C-30 to 40), those parts are copper plated. The exposed portion of the gear which will absorb carbon during carburizing is covered with a specially designed mask; this blocks off the plating solution from the portion of the gear which is to be bare and exposed to carbon penetration. (See Fig. 3.)

Careful preparation of the gears before plating is very essential. They are washed immediately after the machining operations and again by the plating department before masking. After masking they are placed upon special racks, run through an "Anodex" cleaner, given a cold water rinse, a muriatic acid dip, another cold water rinse, then a copper cyanide strike and finally they go into a high speed copper plating tank.

With 10 amperes per sq.ft. of plating area, 30 min. in the plating tank deposits from 0.0005 to 0.001 in. of copper, which is enough to exclude carburization. After unmasking and before carburizing, the gears are run through the same cleaning tanks as before, with an additional acid

Fig. 2 — Unloading Gear Forgings After Normalizing



dip (chromic acid). They are then given a cold water rinse, a hot water rinse, and are blown dry to prevent rusting.

Copper plated gears are inspected 100% for depth of plating on a General Electric thickness gage shown in Fig. 4. There must be at least 0.0005 in. of copper before the gear is carburized, which is the next operation.

Carburizing

AMS 6250 steel, used in most of our aircraft engine gears, is carburized at a temperature of 1650° F. Special alloy spacers carry the weight and thus prevent distortion while the gears are at heat. The gears are placed on these spacers in the carburizing pot and lowered, by means of an electric overhead hoist, into a "Homo-Carb" atmosphere controlled furnace (Fig. 5) for carburizing. Case depth is controlled by the time at temperature and the flow of carburizing fluid into the furnace.

Exhaustive tests have shown us the furnace times and fluid flows which will produce various case depths to within 0.005 in. for various standard furnace loads. Our tests also demonstrated that the vent pipes installed on the furnaces helped to eliminate decarburization in transferring heats from furnace to cooling pit — a very important precaution in order to obtain the hard surface required on Allison gears. At the end of the carburizing cycle the vent pipes are opened, cold air is let in on the outside of the retort wall, and cools it from 1650 to 1500° F. in approximately 45 min.

To illustrate a typical carburizing cycle, a 0.025 to 0.030-in. case depth treatment will be explained: One pint of "Homo-Carb" fluid is used each hour while the gears are being brought up to 1650° F. The fluid flow is increased to 2½ pints per hr. while the temperature is held at 1650° F. After 2 hr. the vent pipes are opened and in about 45 min. the temperature has dropped to 1500° F. The heat is then transferred to a cooling pit and cooled for 3 hr. before unloading.

Case depths are checked by test pieces made

Fig. 3—Gear Surfaces Which Are Later to Be Carburized Are Protected by Specially Designed Masks While the Rest of the Gear Is Copper Plated. Note the different types of gears being masked; also the monorail conveyer

of ½-in. round stock, 2 in. long. They are placed on a wire about 18 in. long, suspended through the vent cap at the time the furnace is loaded. At the end of the time cycle one of these test pins is taken from the vent cap, quenched, cut, polished, and etched in 5% nital. This brings out the total case depth very clearly, and it can be read to within 0.001 in. under a microscope. Another test piece from each load is examined by the laboratory for case depth and maximum carbon content before it is released for hardening or annealing. This insures a file-hard surface.

Annealing and Hardening

Some of our gears have to be annealed for further machining after carburizing but before being hardened. This annealing is also done in the pit type of furnace. The cycle we have found to be most successful has a total time of 6 hr. and gives a structure that is easily machined. Using one pint of "Homo-Carb" fluid per hr. throughout the entire cycle, the temperature is held at 1380° F. for one hour, vent pipes are opened to cool to 1100° F. and this temperature is held for two hours. After cooling to 1000° F. the load is transferred from the furnace to the floor.

This annealing cycle, which has been worked out at Allison after considerable experimenting, gives a Rockwell hardness reading of A-61 to A-68, which is very easy to machine and has proven quite satisfactory.

Teeth of bevel and shaved gears are finished before they come to the heat treating department for carburizing, annealing (if necessary) and hardening. Hardness of these gears is assured by the Rockwell test and the very rigid inspection with a special test file, which covers the entire surface and detects the slightest amount of decarburization. Aside from the file test, we also have exposed areas of core hardness, some of which require further machining. This necessitates a most rigid control of furnace atmospheres so the carbon content of these surfaces may not be changed, or any scale formed.

A typical analysis range of the atmosphere in the hardening furnace is as follows:

CO_2	1.0 to 1.4%
O_2	none
H_2	40.0 to 45.0%
CO	17.2 to 18.0%
Combustibles	1.4 to 3.0%
N_2	33.8 to 39.2%
Dew point	20 to 25° C. (68 to 77° F.)

Furnace atmospheres are checked daily and necessary adjustments made to conform to the desired analysis. The atmosphere is obtained by cracking city gas in an electrically heated generator at 1900° F., using activated alumina impregnated with nickel formate as a catalyst, and cooling the gases before they enter the furnace.

All hardening furnaces are equipped with flame curtains, the gas being supplied by the furnace generator. This curtain prevents the furnace atmosphere from being contaminated when the door is opened.

A rotary type furnace (hearth diameter 48 in.) is used for hardening gears which require die-quenching, the gears being loaded on the rotating metal hearth one by one, and transferred individually to the quenching press after they have made the round trip through the hot furnace. Gears which are not die-quenched are hardened in a pusher type furnace, like the one mentioned above for normalizing rough machined blanks, and quenched automatically.

Fig. 4 — Copper Plated Gears Are Checked on This Thickness Gage, Graduated to 0.0001 In., to Insure Sufficient Plating to Prevent Carbon Penetration

After hardening, all gears are degreased and drawn in a continuous draw furnace with chain belt traveling hearth. Temperatures are low enough so light-walled tote boxes are used for carriers, in which vertical partitions of ply wood form compartments for individual gears, thus preventing contact one with another.

Die-Quenching

Quite a few of our gears require quenching in presses which have a closely controlled time cycle whose length is governed by the size of the gears and is regulated from the central control room. Our gears run from 2 to 5 min. in the

quenching oil. The oil temperature is controlled at 100° F. and 100 gal. per min. flow through each quenching press. Pressure of the oil from the pumps is maintained at 40 lb. Our oil system has a capacity of 15,000 gal.; filters and coolers are located in the basement. All quenching dies are designed and made at the Allison plant. A die crib located in the department has racks for two sets of dies, the duplicate dies being ready for use in case of breakage, to prevent any let-down in production.

Our laboratory has a man continually running specimens through the hardening furnaces and checking the structures. An inspector checks the gears from the quenching presses for tolerance and runout, so it is seldom that a defective gear can get through to the next operation before being caught, the die checked, and necessary adjustments made. A toolmaker is on duty to make changes or repairs when occasion arises.

Allison engine gears are given a shot blast finish in a "Wheelabrator", which has a rotary table upon which rubber baskets are mounted to hold the gears. We use No. 60 shot which is thrown from a slinger wheel and can be controlled in volume. After shot blasting, all gears are inspected 100% dimensionally and visually by file and Rockwell. Then they are dipped in a rust preventive before being sent to the manufacturing departments.

Nitrided Parts

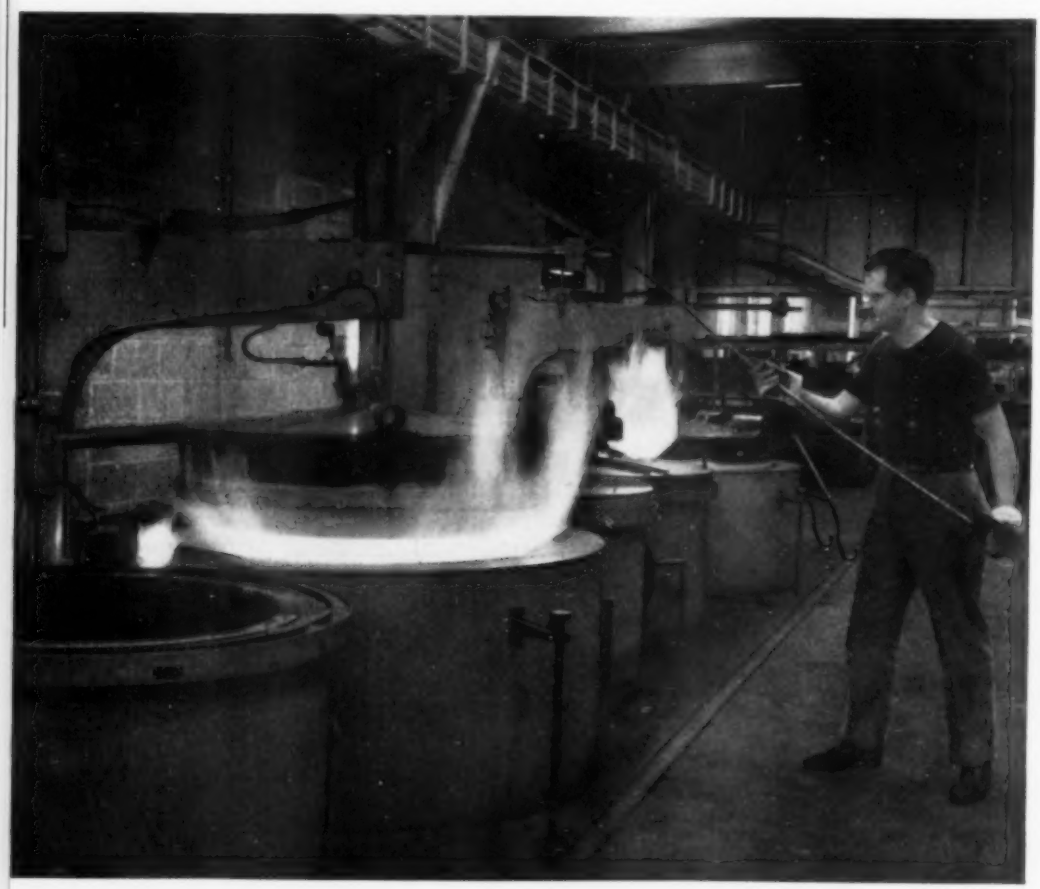
AMS 6470* is the specified steel for nitrided parts. Forgings are normalized by the vendor and are machined into blanks before being given further heat treatment, when they are heated to 1700° F. in a controlled atmosphere furnace for a time sufficient to insure that they remain at temperature for a minimum of 30 min. They are then quenched in a refined petroleum oil below a temperature of 200° F. This treatment gives a hardness range of Rockwell C-52 to 54.

A high draw of 1150° F. for 2 hr. brings down the desired hardness to Rockwell C-34 to 35. After shot blasting and inspection the blanks are returned to the manufacturing department for further machining that may be necessary.

Final heat treatment consists of nitriding in a cylindrical, forced circulation nitriding furnace of the type illustrated in Fig. 6. All parts to be nitrided are carefully cleaned to insure freedom from oil and other foreign matter.

After the parts are loaded and the lid is sealed in an oil seal, the furnace is ready to be purged of air. Flow of ammonia is continued during this purging period until the test for dissociation indicates at least 10% (the furnace being at about 800° F.)

Fig. 5 — Here the "Homo-Carb" Furnace Is Being Opened After the Gears Are Carburized. Proper use of vent pipes gives a quick cool from 1650 to 1500° F. which eliminates decarburization while transferring heats from furnace to cooling pit



*Aircraft quality steel of the following composition: 0.38 to 0.45% C, 0.40 to 0.70% Mn, 0.20 to 0.40% Si, 1.40 to 1.80% Cr, 0.90 to 1.35% Al, 0.30 to 0.45% Mo. Brinell 229 max. as delivered, capable of hardening 0.018 in. in 50 hr. nitriding at 975° F., or 0.015 in. in 35 hr., in either case hardness of 950 Vickers min. at 0.003 in. depth.

Then the power is thrown on the furnace to bring it up to heat. The entire cycle requires an average of 55 hr. of which 48 hr. is the actual nitriding period and the remainder is purge, heat up, and cooling time. Cooling is accomplished by circulating the furnace atmosphere through a water jacketed pipe. When the furnace is cool the ammonia gas is exhausted through the roof.

This cycle produces a silver-gray surface with a nitrided depth averaging 0.017 in. which Rockwells 86 on the 30-N scale. Temperature is controlled from the central control room and the ammonia flow is regulated by means of a flowscope, which the operator adjusts according to gas dissociation readings taken every 2 hr. throughout the entire cycle.

Less Than ½% Scrap

All of us at Allison are proud of the development of our heat treating processes to the point where file-hard gears are being produced in quantity, and at the same time scrap is being held to less than half of one per cent. However, it would be amiss to leave the impression that this development has been easy. It has been possible only through the close cooperation of the vendors and our own laboratories in controlling the steel at the mill before it gets to the forge shop, plus continuous experiments in the positive control of furnace atmospheres, temperatures, and time cycles in the heat treating department. In this connection we might mention that a close check is maintained on all temperature controls and thermocouples, and that everything is held to an accuracy of ±10° F. All furnaces are given daily visual checks and are checked weekly against a potentiometer. Thermocouples are replaced and repaired at regular intervals depending upon the temperature and atmosphere in the furnace.

The development of our fast copper plating process and design of suitable stop-off masks eliminated a great many headaches and broken tools, and saved much time and labor.

Perfection of the die-quenching operations, by the use of properly designed dies and control of oil temperatures and press cycles, was another milestone in the right direction, while the use of alloy spacers to prevent distortion in carburizing was also a great step forward.

We also found that the etching of all test pins, before pulling a load of gears, gave a much more accurate reading than the usual method, which is merely to break a pin and estimate the depth of the surface layer from the fracture.

Even with the most modern processes and the finest heat treating equipment that money can buy, no heat treating department could do a real precision job without careful and competent employees and supervisors who are on their toes and masters of their job at all times. A large share of the credit for the progress the Allison division has made in improving the quality and durability of gears for aircraft engines rightfully belongs to the people who work in the heat treating department.

Fig. 6 — A Battery of Forced Circulation Nitriding Furnaces. Average cycle time is 55 hr. of which 48 is the actual nitriding period

By Given Brewer
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Raised Yield Strength in Bend Tests

"PROPORTIONAL LIMIT" of a metal is a mechanical property that, in the past, was seldom accurately measured and even less frequently used. In such carefully written documents as governmental and national engineering society specifications there is a confusion of terms ("proportional limit", "elastic limit", "yield point", "yield strength", "proof strength") and in the method of determination. This confusion in testing terms and methods has led to much trouble, as pointed out by George P. Lenz, Jr., in *Metal Progress* for February 1942, and because of this situation, at least in part, designers of machines and structures — which of course must act in an elastic manner — have almost universally used a figure for the ultimate strength in their formulas, after dividing it by a healthy figure known as a "factor of safety".

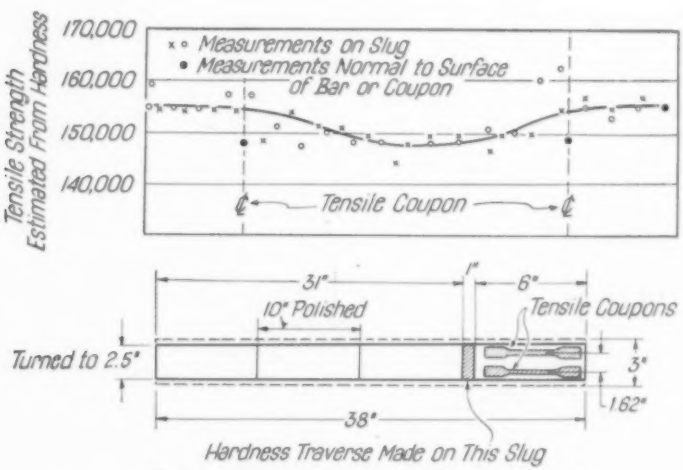


Fig. 1 — Location of Test Pieces, and Hardness Traverse of Heat Treated Bar

Aircraft engineers have led the way to a much more searching analysis of their structures and engines. A new art and science of "stress analysis" has helped them to determine the critical location in a part where it will most likely reach a dangerous stress concentration. Improved methods of testing have formed the basis of this new science, and assured its practitioners that their predictions were actually fulfilled by the part in service. The result has been that a refined design is now based on the proportional limit of the material used, and the electric strain gage, described in detail in *Metal Progress* last July and August, has been a most potent instrument to determine this important property.

According to the A.S.T.M. Standards for 1944, Part I, Metals, page 1009, the proportional limit is "the greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain (Hooke's law)". As is well known, its accurate determination requires an accurate measurement of unit load and corresponding unit stretch on the test piece, the plotting of the results, and the estimation of the point of tangency between proportionality and non-proportionality.

Most of such tests are made on tensile specimens and the fact is little known that when a solid round or square bar is tested in bending the stress at the outside fiber may reach a value 40 to 65% above the tensile proportional limit of the material before the bar suffers a permanent set. This phenomenon of the "raised yield in bending" has received more attention abroad than at home. It has recently been found to apply to round tubing — a matter of particular interest in the structural design of aircraft landing gear.

If the maximum shear energy theory* holds true for a bar in pure bending, such a bar should yield at the tensile proportional limit of the material. The fact that the proportional limit is much higher in bending than in direct tension suggests that yielding is an instability failure wherein the support offered the outer fibers by the less highly stressed inner fibers serves to delay the yield-

*See pages 459 and 479 of Timoshenko's "Strength of Materials; Part II" (2nd Edition).

ing of the outer fibers. Some credence is lent this supposition by the knowledge that in *plastic* bending the outside fibers are supported against necking failure to such an extent that the average tensile strains at failure in bending are 50 to 100% higher than the average obtainable in a pure tension test.

Irrespective of theory, the development engineering group of Consolidated Vultee Aircraft Corp. made an effort to obtain some quantitative data on the raised yield phenomenon in bending. We decided to subject a deep-hardening, round bar of known physical properties to a pure bending moment and record a stress-strain diagram for the outside fibers. For this test we utilized wire type electric strain gages. Accordingly, a 3-in. round bar of S.A.E. 4140, 38 in. long, was taken from stock, heat treated at 1575° F. for 3 hr., quenched in oil and drawn at 800° F. Then to make the bar true and to eliminate completely the decarburized zone the bar was turned to 2.502-in. diameter. Analysis of the bar was 0.36% C, 0.79% Mn, 0.032% P, 0.016% S, 0.28% Si, 1.04% Cr, 0.27% Ni, 0.20% Mo. To determine the variation in physical properties across the diameter of the heat treated bar a transverse slug was cut and a hardness traverse made with results as shown in Fig. 1.

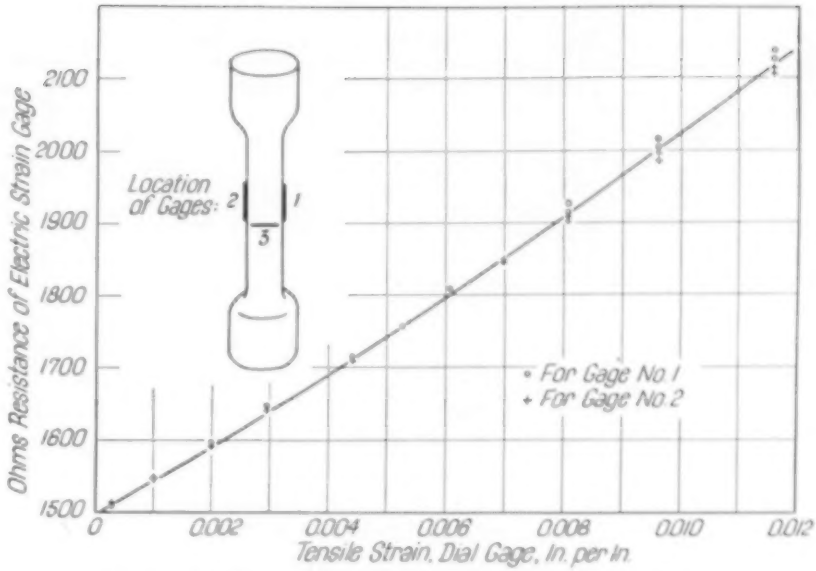


Fig. 2 — Calibration of Electric and Dial Strain Gages

To correlate hardness with physical properties and to double check the recording equipment, two 0.505-in. round tensile coupons (A.S.T.M. standard) were cut from the bar and ¼-in. electric strain gages mounted as shown in Fig. 2. Tensile test data obtained are given in Table I.

The ultimate strength of the bar material as

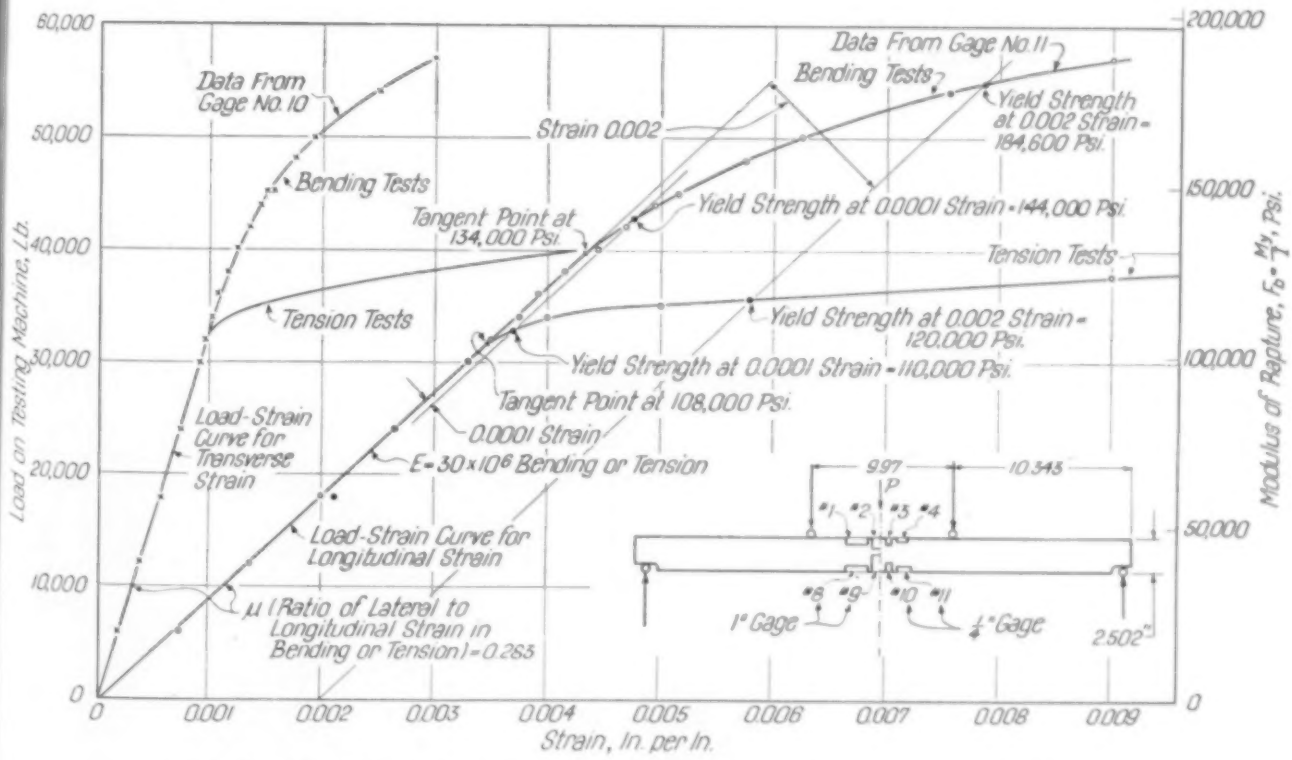


Fig. 3 — Load-Strain Diagram for Tension and Bending Tests, and Diagram Showing Location of Strain Gages and Method of Loading the Bending Coupon

Table I — Tensile Test Data for Two Specimens

Specimen	Yield Strength		Tensile Strength		Elongation		Reduction of Area	Poisson's Ratio★
	0.0001 Strain	0.002 Strain	On Original Area	On Necked Area	In 1 In.	In 2 In.		
A	110,000	120,000	148,000	296,000	29%		64.6%	0.283
B	110,000	120,000	149,500			16%	55.8%	0.283

★Determined from transverse and longitudinal electric strain gages. See Fig. 3.

determined from tension tests is in close agreement with the figure predicted from hardness tests using ordinary conversion tables; therefore, the distribution of tensile properties across the bar, based on hardness (Fig. 1), is validated.

Figure 2 illustrates the relationship between the recording bridge balance readings in ohms for the two longitudinal strain gages against tensile strains as recorded by a dial gage attached to the tensile coupon. It indicates that the electric strain gages function satisfactorily up to strains of at least 0.011 in. per in.

The stress-strain curves in tension of the two round coupons were so close together they are indistinguishable on Fig. 3, which therefore shows the average curve at right, below. At left of this curve is the lateral strain recorded by gage No. 3 on each coupon. The true stress at failure was obtained for specimen A by noting the load at fracture and dividing this value by the final cross-sectional area of the coupon. As shown in Table I the figure is 296,000 psi.

The round bar remaining after cutting off the length used for the hardness traverse and the tensile coupons was used for the bend test. The bend test was made with a pure moment applied over a 9.97-in. section as shown in Fig. 3. This central section was polished and eight electric strain gages, four 1-in. size and four ¼-in. size, were cemented to the surface of the bar at the points of maximum tensile and compressive stress. The bar was then loaded in steps and the strains recorded. It was noted that, in the elastic range, the transverse strains held the same relationship to the longitudinal strains in bending as in tension; therefore, no extra transverse stresses were thrown into the bar by the method of loading and it was unnecessary to correct the strain gage readings for cross sensitivity.

It was also noted that the theoretical outside fiber stress as determined from the ordinary beam formula $F_b = \frac{My}{I}$

where F_b = stress at the extreme fiber, psi., (sometimes termed "the modulus of rupture" when stresses are above the elastic limit).
M = bending moment in in-lb.
y = distance from center of gravity to extreme fiber of cross-section.
I = moment of inertia of the cross-section.

agreed exactly with the measured stresses as determined from the strain gages. Furthermore, the modulus of elasticity E was found to be the same in bending as in tension. The load-strain curve for the bar in bending together with the tension stress-strain curve is shown on Fig. 3.

This modulus of rupture stress, F_b, is plotted on Fig. 3, and up to the proportional limit the actual outside fiber stress is equal to the quantity F_b. Beyond the proportional limit in bending the *actual* outside fiber stress is not known, but as the value F_b is always used in calculating stress this quantity is carried on in Fig. 3 into the plastic region of the curve. It is apparent that in this test the proportional limit in bending was 31% higher — or, more precisely, the yield strength at 0.0001 strain — than the proportional limit in simple tension (the respective figures being 144,000 and 110,000 psi.), and that a value 54% greater than the tensile

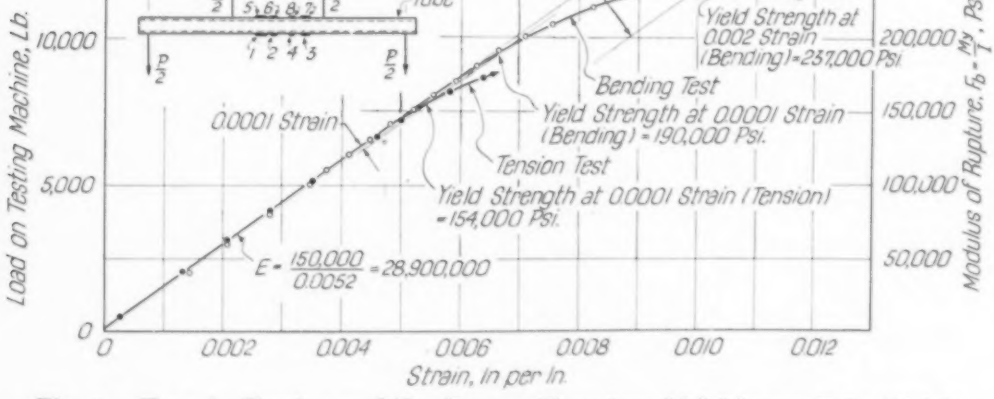


Fig. 4 — Tests in Tension and Bending on Chromium-Molybdenum Tube (1½-In. Outside Diameter, ¼-In. Wall), Heat Treated to 185,000 Psi. Tensile Strength

yield could be used for the modulus of rupture, F_b, without exceeding 0.002 in. per in. permanent set (the figures being 184,600 and 120,000 psi.).

In addition to the solid round bar illustrated in Fig. 3, two round tubes heat treated to 185,000 psi. tensile strength were also subjected to pure bending moments and the stress-strain curve of the outer fiber determined. The first tested was a 1½-in. tube with ¼-in. wall of chromium-molybdenum steel. The specimen was 31 in. long, loaded as shown in Fig. 4. Its ratio of diameter to thickness D/t=6. The load-strain curve is plotted for the outside tension fiber, and the stress (as determined by the beam formula) is also given as the right-hand ordinates.

Using the same type of electric strain gage and equipment a length of the same tubing was tested in direct tension, and the stress-strain curve also plotted for comparison with the curve in bending. The increase in bending proportional limit (0.0001 strain) of this round tube having a D/t ratio of 6 was 23% above the value in tension.

A second tube having a D/t ratio of 23 was also tested in bending and the stress at 0.0001 strain was found to be 175,000 psi.; no tension test was available for this tube so the per cent increase over the value determined from direct tension is unknown.

In addition to these two comparisons made in the laboratory of Consolidated Vultee Aircraft Corp. of the proportional limits in tension and bending, data were available in Air Corps Information Circular No. 686 about tests by G. G. Brown and F. M. Carpenter of two other chromium-molybdenum tubes of higher D/t ratio. These four tests are compared in Fig. 5, and indicate a good correlation.

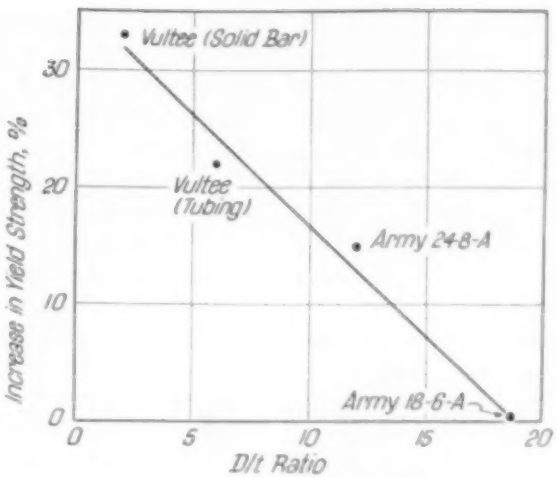


Fig. 5 — Apparent Correlation Between Raised Limit of Proportionality (Yield Strength for 0.0001 Strain as Determined by Bending and by Tension Tests) and D/t Ratio of Tubing Samples Tested

At about the time we were conducting the above experiments we learned that engineers at Menasco Mfg. Co., in analyzing several load-deflection curves for round tubing, noted a marked increase in proportional limit in bending as compared to direct tension tests of the same material. The Menasco Co. plotted load-deflection curves for several round tubes in pure bending, noting the load at which the relationship between load and deflection was no longer linear. The load at the departure from linearity was used to determine the yield stress from the beam formula, $F=\frac{My}{I}$. The stress at the proportional limit in bending was plotted against D/t ratio for the tubing and a positive trend was noted. See Fig. 6.

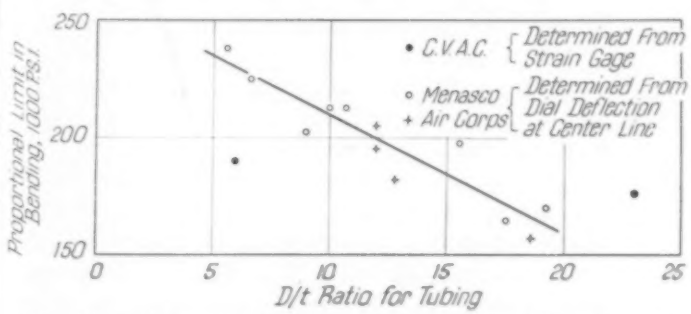


Fig. 6 — Apparent Downward Trend in Proportional Limit in Bending of Tubes as the D/t Ratio Increases. All tests on chromium-molybdenum tubing heat treated to the range of 180,000 to 200,000 ultimate tensile strength

Utilizing the same method as the Menasco Mfg. Co. used, certain data presented in the Air Corps Information Circular No. 686 have been analyzed and these are also carried on Fig. 6, apparently substantiating the Menasco results.

It should be borne in mind when examining these results, that the limit of proportionality is detected sooner and with more accuracy from the system utilizing an electric strain gage at the outermost fiber than from an examination of the load-deflection curve for the beam as a whole. The lesser sensitivity of the load-deflection curve method arises from the fact that at the moment of yielding at the outside fiber of the middle third of the beam the other two thirds of the beam are still in the elastic range and therefore the deflection of the beam as a whole does not increase proportionately with the strain at the most stressed fiber.

It may therefore be concluded that values for

modulus of rupture considerably above the tensile yield strength of the material may be used for tubes under pure bending without permanent set greater than 0.002 in. per in. Figure 6, illustrating the proportional limit in bending vs. D/t ratio, indicates that below D/t = 14 no yielding in bending takes place until stresses actually reach or go above the nominal ultimate strength of the material (180,000 to 200,000 psi.) and this margin increases with decreasing D/t ratio.

The raised proportional limit in bending may well have an effect on the endurance limit of the material as determined by the rotating beam test. It is held in some quarters that endurance limit is directly related to the proportional limit of the material. (See "Prevention of Fatigue of Metals" a book by the staff of Battelle Memorial Institute.) It is also known that ductile materials have an appreciably higher endurance limit as determined from rotating beam tests than as determined from alternate axial tension and compression loading. The phenomenon of raised yield strength in bending may offer some explanation for this discrepancy in results.

Correspondence

Failure of Spring Loops by Stress-Corrosion

MANSFIELD, OHIO

To the Readers of METAL PROGRESS:

A little over a year ago, we had a similar experience to the one noted by Messrs. Brewer and Ihsen in the April issue with tension springs (2 in. o.d.), made from heat treated $\frac{5}{16}$-in. S.A.E. 1065 spring wire, which were required to be pickled and Parkerized as the final finish. The supplier wound the springs in such a way that the coils were tight against each other, or "preloaded", as the saying is.

After final assembly these springs were required to stand a flexure test which simulated the operation of the device. In order to guard against too many rejections due to weak springs, a certain percentage of springs was pre-tested as received. No springs broke during the "pre-test" (although some took a permanent set) but epidemics of breakage were experienced after final assembly (after Parkerize). Broken springs showed a corroded transverse crack, often halfway through the wire, on the *inner* surface of the coils. No cracked springs were ever found on receipt from the spring-maker when they were in the plain condition.

Hydrogen embrittlement was suggested as the cause, even though it was not that the springs were "brittle", but that they contained actual cracks deep enough to cause breakage. The pickle acid was cold, inhibited, 10% sulphuric. Elimination of the pickle did not put an end to the cracks, and no effort was made to bake hydrogen out of the springs after pickling.

The springs were given a stress relieving anneal at 550° F. (by the maker), so, in order to have some highly susceptible samples, a few were furnished without this heat treatment. After the samples were Magnaflux tested and found to be 100% free from cracks, half were neither pre-flexed nor pickled but were given the usual 30-min. Parkerize, after which the Magnaflux test showed that over half of the samples were cracked and over half of the cracked springs broke when flexed. The cracks were not as deep as some we had seen; the elimination of the pickle probably reduced the severity of the effect.

The other half of the crack-free, non-heat treated samples were all pre-tested (pre-flexed) and then Parkerized without pickling. Less than half of these samples showed cracks in the Magnaflux test and none of them were deep enough to cause breakage when flexed. Most of the cracked springs which withstood one flexure would withstand a double flexing. The test proved that pre-flexing removed enough of the stress so that the springs would not break after Parkerizing, but neither pre-flexing nor elimination of the pickle was adequate to remove the cause of the trouble. These results also showed that the many tests made on springs, pre-flexed 100% "to show freedom from cracks", were meaningless because of the fact that flexing removed enough stress to practically eliminate spring breakage in the final flexure test. (We had used pre-flexing as a test for cracks because Magnaflux testing had to be done on the outside.)

Though the above tests were made on non-heat treated springs, larger lots of unflexed springs were simultaneously showing as high as 30% breakage on final flexing, even though they had not been pickled.

No difference in Rockwell hardness could be detected between springs which were stress-relief annealed and those which had not had this treatment, nor could we find measurable difference between the heat treated wire and the coiled spring. Straight lengths of wire were crudely bent into small coils which cracked during pickle and/or Parkerizing, whereas straight lengths pickled and Parkerized could be bent severely with impunity.

We concluded that the cracks were caused by stress-corrosion in the pickling or Parkerizing vats, and, after laying the facts before our customer, received permission to protect the springs by painting. No springs have broken since then.

This type of pre-loaded spring is apparently more highly stressed than the ordinary type and is liable to crack during pickling or Parkerizing, regardless of preliminary history such as stress relieving anneal, flexing, or other treatment. Without the Magnaflux test, we might have concluded that 100% pre-flexing and elimination of the pickle produced a satisfactory article, since little, if any, spring breakage resulted, but the shallow cracks likely to be present would have made an inferior device with lowered fatigue resistance. The stress analysis presented by Messrs. Brewer and Ihsen now completes the picture.

R. W. PARSONS
Chief Metallurgist
The Ohio Brass Co.

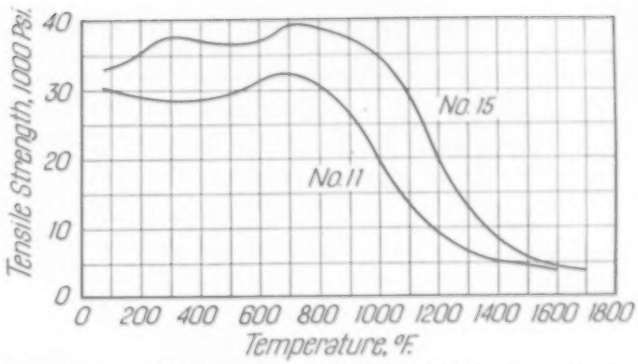
Hot Strength of Two Cast Irons

LANCASTER, OHIO

To the Readers of METAL PROGRESS:

It may be of value to place on record the results of a series of tensile tests on high strength cast iron, made at elevated temperatures. The work was done at Valparaiso (Ind.) University in equipment that is proper for short time, high temperature testing. The test bars were machined from round bars about 1 x 24 in., cast for this purpose in dry sand molds. Final shape was like the ½-in. round specimen illustrated on page 132 of the Metals Handbook, except that the reduced section was about 3½ in. long.

Two alloys were tested, both cupola products, made under close metallurgical control. Alten's Alloy No. 11 is a general purpose iron for machinery parts, and is heat resistant to a moderate degree. Its microstructure is mainly fine pearlite with A.F.A. class 3-A graphite flakes; the excess cementite is in small islands in random orientation. Alten's Alloy No. 15 is a chromium-molybdenum-vanadium iron, produced specifically for higher temperature applications. Its microstructure contains a matrix of fine pearlite and the cementite is in extensive dendritic pattern; graphite is as A.F.A. class 3-A flakes.



Short Time, High Temperature Tensile Tests on High Grade Machinery Iron (No. 11) and Alloy Iron (No. 15)

The above figure gives the results of the high temperature tests and the tabulation the average chemistry, flexure and hardness.

H. KENNETH MCGRATH
Alten's Foundry & Machine Works

Average Analysis and Strength

	No. 11	No. 15
Silicon	1.74%	1.82%
Sulphur	0.112	0.072
Phosphorus	0.369	0.164
Manganese	0.51	0.61
Total carbon	3.53	3.54
Graphite	2.74	3.13
Combined carbon	0.79	0.41
Chromium	0.07	1.46
Nickel	Trace	0.16
Molybdenum	0.03	0.58
Vanadium	—	0.08
Copper	—	0.04
Brinell hardness	200	270
Transverse strength	2000 lb.	1800 lb.
Deflection	0.22 in.	0.13 in.

Copper Plate as a Stop-Off When Nitriding

DETROIT, MICH.

To the Readers of METAL PROGRESS:

Our article in the February issue on the use of copper plate as a stop-off in selective nitriding was based on results obtained when nitriding a collar having the surface finish used in regular production at Motor Products Corp. This finish was obtained by grinding on a Norton 3746-K-5 wheel (46 grit) and is between 25 and 35 micro-inches as measured on the profilometer.

Further tests have now been carried out to determine the amount of copper plate required for various surface finishes. Twelve collars with four types of surface finishes were plated by the "Unichrome Copper Plating Process" to different thicknesses to deter-

Relation Between Prior Surface Finish and Protection Necessary

Finish and Surface Finish, Micro-Inches	Thickness of Copper Plate	Test Results After Nitriding
Machining		
40 to 50	0.00078 in.	No case
40 to 50	0.0010	No case
40 to 50	0.0013	No case
Rough grinding		
25 to 30	0.0002	Penetration
25 to 35	0.0004	No case
25 to 30	0.0005	No case
Finish grinding		
12	0.0002	No case
13	0.0004	No case
13	0.0005	No case
Finish grind and polish		
3.0 to 3.5	0.0002	No case
3.5 to 4.0	0.0004	No case
3.0 to 5.0	0.0005	No case
Machining, stress relief and sand blast		
....	0.0008	Penetration
....	0.0010	Penetration
....	0.00125	No case

mine approximately the minimum thickness required to protect during a nitriding cycle of 154 hr. at 970° F. Results are contained in the adjoining table. While the points of failure for the various finishes were not discovered in all cases, it was established that relatively low thicknesses of copper sufficed to give satisfactory protection to machined, ground, or polished finishes of the micro-inch values listed. It was also shown that the sand blasted surface required a somewhat heavier deposit.

As a matter of interest and in an attempt to carry out a life test, one collar having a rough ground finish and plated with 0.0008 in. copper was nitrided for five complete cycles, each cycle being 154 hr. at 970° F., giving a total time in the furnace of 770 hr. The copper plate was not penetrated by nitrogen.

A point to be emphasized is that moisture in the nitriding furnace is a hazard to copper plate. The bulk of our production is nitrided in a Holcroft continuous furnace of the pusher type. Being a continuous furnace the amount of moisture in the nitriding atmosphere is negligible. Some of our work, however, is run through a Westinghouse batch type intermittent furnace; no failures have resulted, although some discoloration of the copper plate usually occurs due to the moisture present. Anyone using copper plate as a stop-off in an intermittent type of furnace would do well to make certain that the system is as free of moisture as possible, and all air should be displaced by anhydrous ammonia before bringing the furnace up to heat.

Upward of 150,000 collars have been copper plated by the Unichrome Copper Plating Process and selectively nitrided in the Motor Products Corp. plant with very satisfactory results. The use of copper plate reduced the scrap on the job to percentages as low as ½ of 1% from all causes.

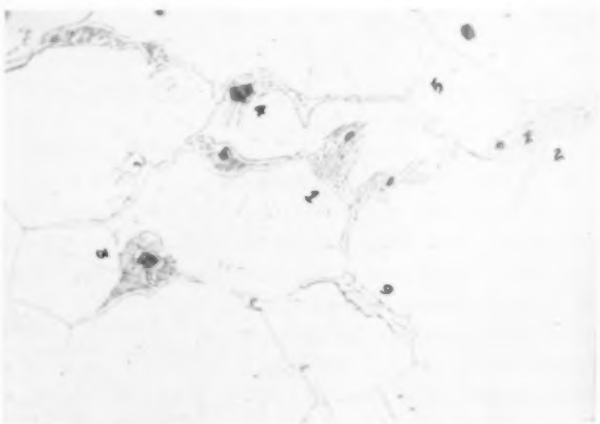
W. V. Sternberger
Chief Metallurgist
Motor Products Corp.
and E. R. Fahy
Chemical Engineer
United Chromium, Inc.

Metallurgical Zoo

LaGrange, Ill.

To the Readers of Metal Progress:

You have seen, reproduced in the correspondence pages of *Metal Progress* at frequent intervals, and certainly when looking through your own microscope, some appearances that were far enough from the usual metallurgical forms to make you rub your eyes and resolve never to take too many Martinis again, no matter what the temptation. Recently



I discovered a veritable zoo! Twirl the print and see the animals, numbered as follows:

1. Rabbit (leaping)
2. Muskrat (slinking)
3. Goat (with whiskers)
4. Giraffe (discouraged)
5. Giraffe (undernourished)
6. Turtle (basking)

J. A. Erickson
Metallurgist
Electro Motive Division
General Motors Corp.

Atomic Power and Atomic Bombs

A Condensation of the "Smyth Report"

By Ralph P. Johnson
Research Laboratory, General Electric Co. Schenectady, N. Y.

ON AUGUST 6, 1945, the President of the United States announced that an "atomic bomb" with more power than 20,000 tons of TNT had been dropped from an American airplane on Hiroshima, Japan. Three days later a second atomic bomb was released on Nagasaki.

These two explosions stirred up such a wave of interest and excitement in this country that the surrender of Japan, coming within the next two weeks, was almost an anticlimax. Only the youngsters, toughened to their daily dose of marvels in the comic strips, were prepared to take atomic bombs as a matter of course. Among adults the reactions ranged from jubilation to serious alarm: "I have been reading", a subscriber tells the Editor of the *Oklahoma City Times* on August 10, "about the new atomic bomb. I do not like the thing. I think it entirely possible that, like a violin striking the right note and being able to shatter a glass, scientists fooling with bursting atoms might conceivably strike the right note, so to speak, and blow this whole universe to smithereens and ourselves along with it." Such fears were widely voiced even by sober engineers and technical men. For example, the Editor of *Metal Progress* in the September issue quotes with approving trepidation a contribution printed five years earlier describing briefly the fission of uranium 235 and mentioning the horrid chance that the whole world might be blown up by a triggered reaction in iron or nickel. The early newspaper accounts purporting to explain how atomic energy had been harnessed and released in the bomb did little to calm these fears.

It must be said, however, that physicists generally felt little increased uneasiness over the immediate fate of the earth, but for them the announcement raised many other questions of extreme interest. They recalled that early in 1939 certain unpredicted properties of the metallic element uranium had been discovered; that this discovery had opened up for the first time a reasonable prospect of producing "atomic power" in useful quantities; and that this possibility had been studied, both experimentally and theoretically, with great intensity during the succeeding 18 months. Since the middle of 1940, however, the whole field had been under a blanket of absolute censorship. For five years there had been no public discussion of the subject. The explosions in Japan showed that the secret research of these five years had been successful.

The questions arising in physicists' minds at that time were these: Had success been reached by following the paths that looked most likely in 1940, or had it been necessary to find some entirely new approach? Was a superlative weapon of destruction the only result, or had ways been found for controlling the power for constructive purposes? How had the problems of materials and techniques that seemed so exceedingly difficult in 1940 been solved? How large an enterprise had it been? What men and what organizations had been most closely concerned with it?

Even among the many scientists who had worked on one phase or another of the bomb project, only a very few had been in position to satisfy their curiosity on all such questions.

The Smyth Report

The War Department, foreseeing that news of an atomic bomb would excite public interest to a high pitch and recognizing a responsibility to inform the citizens, had asked Prof. H. D. Smyth, chairman of the department of physics of Princeton University and a leader in the work on the bomb, to write an account of the entire

project. This report, a document of nearly 200 closely spaced type-written pages, was ready for release shortly after the two bombs had been dropped. It is described in the preface as "a matter-of-fact, general account of work in the United States since 1939 aimed at the production of such bombs". The report is coherent and readable and contains much detailed information about what has been accomplished and how it has been done. Both the English and the Canadian governments have issued much shorter statements concerning their roles in the program, but they contain little additional information other than notes on personnel and organization.

The Smyth Report can hardly be condensed except by leaving out certain parts wholesale. For this review, the choice has been made to deal most fully with the processes that go on in the exploding bomb and in the arrangements for producing atomic power at a controlled rate, and to discuss some of the technical problems — particularly those involving metallurgy — that had to be solved. The men who were responsible for various parts of the work will not be named, nor will any attempt be made to trace out the complicated organization that developed as the project expanded. For these matters, and for a skillful placing of the different phases of the work in their proper historical perspective, reference must be made to the original document. It would be a disservice to the reader not to recommend the Smyth Report strongly as a fascinating account of a tremendous job, completed on schedule.

The present author has paraphrased much of the matter contained in the Smyth Report. Quotes are used to indicate verbatim extracts. In the preliminary statement of the elementary science and the fundamental experiments of nuclear physics he has drawn upon the common knowledge of this branch of science.

A Bare Summary

For those who are not disposed to read either the Smyth Report or much more of this, the following bare summary is presented:

Controlled power in large quantities has been produced from the disintegration of atomic nuclei. When a pile of purified graphite containing slugs of pure uranium metal in a suitable lattice arrangement is built up beyond a certain critical size, a self-sustained "chain reaction" progresses among the uranium nuclei, and the pile loses energy to its surroundings in the form of heat. The rate of the reaction can be controlled by pushing barriers of cadmium or boron steel here and there into the pile more or less deeply. While the chain reaction is occurring some of the uranium is changed to a new chemical element called plutonium, which can be readily separated from the uranium and used as the explosive in an atomic bomb. Large graphite-uranium piles have been constructed solely to produce this explosive, the heat from the reaction being thrown away as a troublesome byproduct. Another explosive suitable for atomic bombs is made from uranium itself by separating and collecting the light uranium atoms from the heavy uranium atoms, the two varieties being mixed in the metal extracted from natural ore in the proportion of one light atom to 140 heavy atoms.

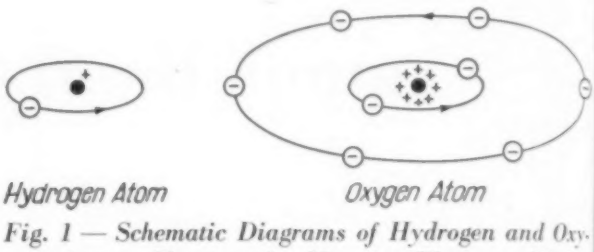


Fig. 1 — Schematic Diagrams of Hydrogen and Oxygen Atoms, Showing the Negative Electrons Moving in Orbits Around the Positively-Charged Nucleus

Two ways of doing this more difficult separation on a large scale have been perfected. Small masses of either uranium or plutonium, though radioactive, are not explosive. An atomic bomb is made by bringing together quickly, at the point where the explosion is desired, two or more smaller pieces of this light-atom uranium (or of plutonium) and merging them into a larger mass, big enough so that their combined size becomes explosive. The explosion is a nearly instantaneous chain reaction similar to the chain reaction that is used, at a controlled slow rate, for making plutonium. The research has been directed steadily toward the goal of an atomic bomb, and possible methods of using the power from such reactions for productive purposes have therefore not yet been deeply explored.

Some Background of Elementary Physics

Explaining the operation of the atomic power pile and its cousin, the atomic bomb, means answering three questions:

1. Where does the energy come from, and in what form is it stored up before the explosion or the power-production takes place?
2. How is the energy released?
3. How can the rate of energy release — the power output — be controlled?

These same questions can be asked, of course, about any explosion or power source. It

turns out that the answers are about the same whether the reaction is of this new atomic sort or one of those (such as combustion of fuel) with which we are familiar. The combination of hydrogen and oxygen to produce water vapor, for example, can be controlled as an oxy-hydrogen flame, giving off energy steadily in the form of heat and light, or it can be made to occur with explosive rapidity. This familiar chemical reaction resembles in so many ways the nuclear reactions that go on in the pile and in the atomic bomb that it will be convenient to refer to it occasionally as a parallel for the nuclear reactions.

The Source of the Energy

First, then, what is the source of the energy continually thrown out by an oxy-hydrogen flame? Imagine four hydrogen atoms and two oxygen atoms. As shown in Fig. 1, each hydrogen atom is to be thought of as a tiny nucleus (a "proton") charged with one unit of positive electricity, with an electron, much lighter than the proton and charged with one unit of negative electricity, revolving around the nucleus in some sort of orbit. Each oxygen atom is to be thought of as a more complicated system consisting of a nucleus, almost exactly 16 times as heavy as the proton, with eight units of positive electricity on the nucleus and eight electrons revolving in various orbits about it.

(It would doubtless be instructive, if space permitted, to give a brief account of the fundamental experiments made between 1897 and 1910 that led Rutherford to explain the structure of the atom in this way. We can only pause to comment that this indeed was an extraordinary change in viewpoint, for ever since the early Greek philosophers advanced some ideas about the ultimate particles of matter they were regarded as indivisible — the word "atom" means just that.

These six atoms — four hydrogens and two oxygens — can be arranged in two different ways that are stable under ordinary conditions of temperature and pressure: They can be paired off into two hydrogen molecules ($2H_2$) and one oxygen molecule (O_2), or they can be arranged in threes to form two water molecules ($2H_2O$). It makes no difference to the nuclei of the six atoms which of these arrangements is chosen — but the orbits of the outer electrons are different in the two arrangements. It happens that the *energy* contained within the second arrangement — two water molecules — is somewhat less than the energy of the first. That is to say, if two molecules of hydrogen and one molecule of oxygen can be torn apart into four atoms of hydrogen and two atoms of oxygen, and these are then reassembled into two water molecules, this process will modify the electron orbits and arrangements in the "outer shells" of the atoms and set free a certain amount of energy which is the difference between the energies of the two arrangements. The chemist expresses it by saying that the reaction $2H_2+O_2 \rightarrow 2H_2O$ is "exothermic", and the measurements show that 1461 kilogram-calories of energy are released for every pound of water vapor made in this way.

A similar process, namely, a rearrangement of atoms into molecules that are more stable (that contain, in other words, less stored energy), occurs in every combustive or explosive chemical reaction. Again, the process is associated with changes in the electron *orbits* rather than in the atomic nuclei. When anthracite coal burns in air, carbon atoms are being torn from their attachment with other carbon atoms and oxygen molecules are being sundered into oxygen atoms and the several bits are finally coming together to form carbon dioxide molecules, and considerable heat (energy) is evolved but at a quite moderate rate. When TNT explodes, the complicated trinitrotoluene molecules are being ripped apart and their hydrogen, carbon, nitrogen and oxygen atoms are getting together to form more stable compounds, and much heat is generated at a very rapid rate.

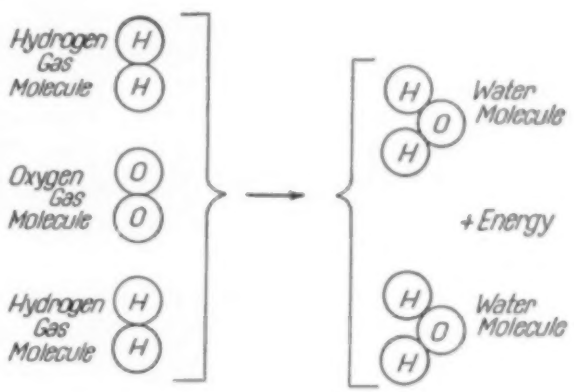


Fig. 2 — Energy Is Released When the Atoms in Hydrogen and Oxygen Molecules Are Rearranged to Form Water Molecules

All this is no news, of course. It is reviewed here solely as a preface to the statement that the energy released in an atomic bomb or in a graphite-uranium power pile comes from a closely associated source. This evolved energy was previously stored up in the *nuclei* of the atoms — those relatively heavy central structures that go unaffected through ordinary chemical reactions. The energy is set free when these nuclei change to other nuclei that are more stable.

The Chemistry of Nuclei This bald statement is not meant to be a satisfying answer to the question: "Where does the energy come from?" One is entitled to ask: "What are the nuclei made of? How are the parts stuck together? How can they be jolted apart to allow rearrangement? How can the energy stored up in a nucleus be measured? What kind of nuclei are used in the pile and in the bomb? What is the reaction there, and what are the more stable nuclei that are formed?"

Such questions call for a brief consideration of what might be called the "chemistry" of nuclei — what is in them, and how they react.

Fortunately, the chemistry of nuclei is no such vast expanse as is the ordinary chemistry of atoms. In place of the 92 different chemical elements there are only two different nuclear building-blocks, and in place of the millions of chemical compounds so far isolated only about 750 different nuclei are known. Of course, the study of nuclei is a comparatively recent business — 50 years ago no one had any very compelling reason for supposing even that an atom had a nucleus — and many points about the behavior of nuclei are still mysterious. It is probable, in fact, that later knowledge will make it necessary to modify the simple picture that all nuclei contain only two kinds of elementary particles. This picture is sufficiently complete, however, for the present discussion.

Protons One of the two elementary particles, the proton, has already been mentioned as the nucleus of the ordinary hydrogen atom, the simplest of all nuclei. A few free protons, otherwise known as positive hydrogen ions, occur in every hydrogen flame. They are found, in much greater concentration, in the hydrogen welding arc.

Neutrons The other elementary particle, the neutron, is almost identical with the proton in mass, but carries no electrical charge. Its lack of electrical charge makes the neutron a difficult particle to study. Unlike the positively-charged proton, which cannot move through a solid or gas without being hindered and quickly stopped by the negatively-charged electrons, a free neutron keeps on going freely until it hits an atomic nucleus. Such collisions are relatively rare, even in "solid" material, because the nuclei are *very* small compared with the distances between them. For example, in solid aluminum the nuclei are separated by approximately 10,000 nuclear diameters, and from the viewpoint of a wandering neutron, a block of aluminum is nearly all empty space, in which it can travel an inch or so before hitting anything. A fast proton — a charged particle — going through a gas leaves a trail of ions, or atoms that have had one or more of their negative electrons pulled off by the positive charge on the passing particle. A neutron, contrastingly, leaves no evidence of its passage except at the rare points where it hits a nucleus. So also the charged proton can be speeded up, slowed down, or sent on curved paths by suitable electric or magnetic fields, but the only thing man can do to a free neutron is to slow it down by letting it bounce around from one nucleus to another. A free neutron, moreover, is hard to make and to keep; the only known source is a nucleus that is rearranging itself into a more stable form and is discarding a neutron as a spare part, and every neutron so freed is soon absorbed by some other nucleus it happens to hit.

Because of its elusive nature the neutron was not even suspected before 1930, and the experiments that finally proved its existence were not finished until 1932. However, it has become, because of these same characteristics, perhaps the most useful of the various particles that are used in studying nuclei. As will appear, free neutrons play an essential part in the operation of the atomic power pile and the atomic bomb.

The Contents of a Nucleus The nuclei, then, are simply compact collections of protons and neutrons. A single proton is the nucleus of ordinary hydrogen.

One proton and one neutron together make a nucleus almost exactly twice as heavy as a proton but having only one unit of positive charge. Such a nucleus therefore requires one orbital

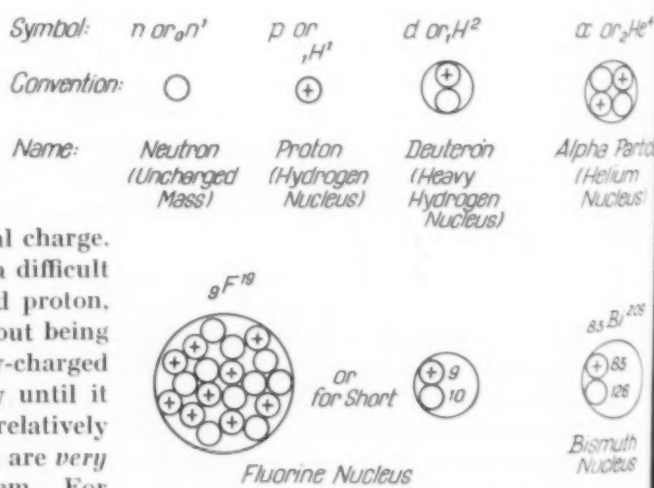


Fig. 3 — The Two Elementary Building Blocks of Nuclei Are the Neutron n and the Proton p. A few schematic diagrams show that nuclei are compact collections of the two kinds of particles in approximately the same number

electron to make an electrical balance, and the resulting atom is just like an ordinary hydrogen atom in its chemical properties (since, as remarked above, the *chemical* properties are governed by the number of outer electrons in the "planetary system" of the atom).

It is now known, since 1932, that one out of every 5000 hydrogen atoms occurring on the earth has such a double-weight nucleus, and methods have been developed for separating out these double-weight atoms to make considerable quantities of "heavy hydrogen", which can be combined with oxygen into such a compound as "heavy water". Because of its special importance, heavy hydrogen is given a name of its own, "deuterium", and the nucleus with one proton and one neutron is called a "deuteron".

The nucleus of the inert gas helium, the next-simplest element after hydrogen, contains two protons and two neutrons; its *mass* is therefore four units and its *charge* two units, and it requires two electrons revolving about it to make an ordinary neutral helium atom. This nucleus also has a special name, the "alpha particle", so named from a radiation which was investigated a long time before its relationship to helium was established.

The fluorine nucleus, to take a more complicated example, contains 9 protons and 10 neutrons, has a mass of 19, and needs 9 electrons about it to make a fluorine atom. The bismuth nucleus contains 83 protons and 126 neutrons; its mass is 209, its charge is 83.

These examples illustrate how nuclei are built up out of protons and neutrons. The mass of a nucleus (in units of proton mass) is the sum of the numbers of protons and neutrons in the nucleus; its charge (in units of proton or electron charge — the two are identical) is just the number of protons present. The charge, not the mass, determines how many electrons must be revolving about the nucleus to make a normal electrically-neutral or non-ionized atom. Because the ordinary chemical properties depend entirely on how many of these orbital electrons the atom has, atoms whose nuclei contain a definite number of protons are quite alike chemically, no matter how many neutrons are present in the nucleus along with the protons.

Shorthand Symbols for Nuclei It is useful to have a shorthand symbol for each kind of nucleus, and the following practice has been universally adopted: The number of protons (that is, the electrical charge) is written as a subscript in front of the chemical symbol for the element. The total number of particles, protons plus neutrons (that is, the nuclear mass) is written as a superscript after the chemical symbol. The nuclei of helium, fluorine and bismuth described above are denoted, in this manner, by $_{2}He^{4}$, $_{9}F^{19}$ and $_{83}Bi^{209}$.

Consistent with this notation, the proton is indicated by $_{1}p^{1}$ (or sometimes, to emphasize that it is a hydrogen nucleus, by $_{1}H^{1}$), the neutron by $_{0}n^{1}$, and the deuteron by $_{1}d^{2}$ or $_{1}H^{2}$. The electron, with one unit of negative charge and a mass that is insignificant in comparison with the mass of a proton or neutron (1850 electrons to one neutron) is symbolized by $_{-1}e^{0}$.

No one yet understands satisfactorily just how protons and neutrons manage to stick together in a nucleus. The protons, being all positively charged, would certainly be expected to repel one another and so resist packing into a small volume, and there is no obvious property of the neutrons that enables them to hold a nucleus together in spite of the electrostatic repulsion among the protons. Nevertheless, somehow the trick is done, and a considerable number — about 250, in fact — of different nuclei exist in nature, ranging in charge and mass from hydrogen $_{1}H^{1}$ to uranium $_{92}U^{238}$.

Isotopes In all these naturally-occurring nuclei the number of neutrons is equal to the number of protons or somewhat larger, with the exception only of $_{1}H^{1}$ and a very rare form of helium $_{2}He^{3}$. As the number of protons increases the excess number of neutrons tends also to increase. This trend can be seen in the sequence of nuclei already mentioned: $_{2}He^{4}$, $_{9}F^{19}$, $_{83}Bi^{209}$ and $_{92}U^{238}$.

However, the number of neutrons going with a certain number of protons is not rigidly fixed except in certain special cases. (Fluorine and bismuth are, in fact, such instances.) More usually the number of neutrons is variable within a small range, and nuclei occur commonly with the same charge but with differing masses. As doubtless is well known to most readers of this article, such nuclei are known as "isotopes" of one another, from two Greek words meaning "the same place" occupied in the periodic table of elements. Since the nuclear charge is the same for all members of a set of isotopes, the surrounding orbital electrons and chemical properties of the atoms are the same. Indeed, in nature the atoms of differing mass are homogeneously mixed up in certain proportions. Chromium, for example, is a mixture of four natural isotopes in the following proportions: $_{24}Cr^{50}$, 4.49%; $_{24}Cr^{52}$, 83.78%; $_{24}Cr^{53}$, 9.43%; $_{24}Cr^{54}$, 2.30%. Uranium, the heaviest element and a metal, which figures

largely in the following discussion, is a mixture of three natural isotopes: $_{92}U^{234}$, 0.006%; $_{92}U^{235}$, 0.71%; $_{92}U^{238}$, 99.28%.

The Masses of Nuclei The internal energies of these naturally-occurring nuclei are measured by a roundabout but exceedingly interesting method:

First, the atoms of the element under investigation are ionized by knocking one orbital electron off from each atom, using fast free electrons as bullets. The ions are then sent through certain combinations of electric and magnetic fields so chosen that the path an ion takes is determined by its mass — that is, by the mass of its nucleus, since all the ions have the same number of orbital electrons left. In these magnetic or electric fields the different isotopes of the given element are sorted out; each variety finally arrives at a definite place on a photographic plate or whatever other detector or counting mechanism is being used. The relative abundance of each isotope, and its mass, can thus be measured.

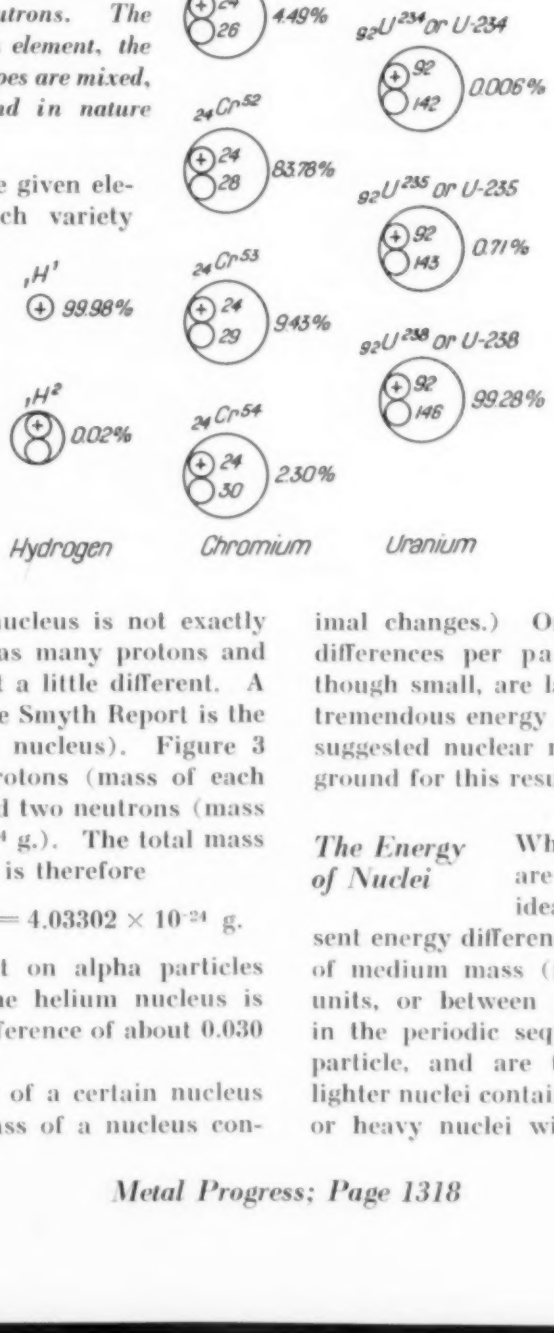


Fig. 4 — Examples of Isotopes, Nuclei Having the Same Number of Protons But Differing Numbers of Neutrons. The percentages indicate, for each element, the proportions in which the isotopes are mixed, wherever the element is found in nature

If the measurement of mass is made precisely, a curious thing appears: The mass of a nucleus is not exactly the sum of the masses of as many protons and neutrons as it contains, but a little different. A specific example given in the Smyth Report is the alpha particle (the helium nucleus). Figure 3 shows it to contain two protons (mass of each being 1.00758×10^{-24} g.) and two neutrons (mass of each being 1.00893×10^{-24} g.). The total mass of the separate components is therefore

$$2 \times 1.00758 + 2 \times 1.00893 = 4.03302 \times 10^{-24} \text{ g.}$$

However, direct experiment on alpha particles shows that the mass of the helium nucleus is only 4.00280×10^{-24} g., a difference of about 0.030 mass units.

Furthermore, the mass of a certain nucleus is not exactly twice the mass of a nucleus containing half as many protons and neutrons — even in the same proportion, each to each — but a little different. These differences are small, usually much less than 1%, but they are large enough to be measured with assurance.

It really appears, from such measurements, that the mass of a neutron or proton depends on what kind of nucleus it finds itself in!

Mass and Energy The situation is reminiscent of the reaction between hydrogen and oxygen mentioned earlier, where the energy of the atoms was found to be different, depending on whether they were associated as hydrogen and oxygen molecules or as molecules of water vapor. In that chemical reaction it was an energy difference; with the nuclei, what is measured is a difference in mass. However, as early as 1905 Einstein had proposed, as a consequence of his relativity theory, that mass and energy are not two entirely distinct things but are different manifestations of the same entity, and that either one can be converted into the other. The theory led to a mathematical equation containing a conversion factor so large that the energies evolved or absorbed in ordinary chemical reactions correspond to an entirely imperceptible change of mass per atom. (Hence the principle of conservation of mass held true, because the most precise balances could not measure the infinitesimal changes.) On the other hand, the mass differences per particle found among nuclei, though small, are large enough to correspond to tremendous energy differences. Einstein himself suggested nuclear reactions as a likely proving-ground for this result of his theory.

The Energy of Nuclei When the data on nuclear masses are reviewed in the light of the idea that mass differences represent energy differences, it appears that the nuclei of medium mass (roughly between 40 and 100 units, or between potassium and molybdenum in the periodic sequence) have less energy per particle, and are therefore more stable, than lighter nuclei containing either very few particles, or heavy nuclei with very many particles. It

would follow that if two light nuclei could be joined up into a medium-mass nucleus, or if a heavy nucleus could be broken down into medium-mass nuclei, energy would be liberated — and in quantities per particle far beyond the scale of the energies released in ordinary chemical reactions.

Since 1905, as ways of studying nuclei have multiplied and knowledge of their behavior has increased, this idea that mass and energy are interchangeable has been verified experimentally for many different cases. Nuclei have been changed into other more stable nuclei, and in every such transformation that has been studied in detail the energy released in the form of radiation and kinetic energy of the particles checks with the difference in mass between the initial reactants and the final products, in accordance with Einstein's equation.

Again for a specific example let us cite a 1932 experiment noted in the Smyth Report: When lithium is bombarded with protons alpha particles are ejected from the target. The nuclear reaction is written as follows:

$$_3Li^7 + _1H^1 \rightarrow _2He^4 + _2He^4$$

Computing mass we find that 3.07×10^{-26} g. of mass have disappeared. According to Einstein's equation this would mean the evolution of 27.6×10^{-6} ergs of energy. (Actually the energy balance, as measured experimentally, is $+27.2 \times 10^{-6}$ ergs.) Thus, long before the atomic bomb, the physicists' experiments that the public knew under the general name of "atom-smashing" had confirmed that enormous energy is there within the atom, stored up in the form of mass. What was lacking was a way to get it out on a scale larger than a few atoms at a time.

Natural Radioactivity The "fooling with bursting atoms" that the Oklahoman thought so perilous has actually been going on since 1896. The first hint that nuclei are not permanent and immutable was the accidental observation that photographic plates were blackened when certain minerals were left nearby. This observation, followed up, resulted after many years in the knowledge that the nine elements in nature whose nuclei contain more than 83 protons are all *unstable!* Their nuclei break down all by themselves, some kinds at a rapid rate and other kinds slowly. The result of each transformation is another nucleus, and this in turn breaks down into another nucleus, each time with the ejection of energy and various spare parts, until finally a stable isotope of the element lead is reached.

Atom-Smashing Among the high-speed particles emitted by some of these "naturally radioactive" nuclei when they break down is the alpha particle, the doubly-charged helium nucleus already mentioned (Fig. 3). In 1919, in a study of the average range of travel of alpha particles in air, it was found that when an alpha particle strikes a nitrogen nucleus, the latter is sometimes changed into an oxygen nucleus and a proton is released. The reaction may be written as follows:

$$_2He^4 + _7N^{14} \rightarrow _8O^{17} + _1H^1$$

This transformation of what had hitherto been regarded as a very stable nucleus into another nucleus was the first indication that nuclei are not completely immune to human tampering.

In the succeeding years many such transformations have been made — at first only when the fast particles and radiations from natural radioactive nuclei were used as projectiles. Later experiments used protons and deuterons brought up to very high speed by man-made devices such as the "cyclotron" (Fig. 5) and the "electrostatic generator". Since 1932, when neutrons were recognized among the debris from nuclei in the process of transformation, neutrons have been widely used for effecting such nuclear transformations. The neutron, because it has no

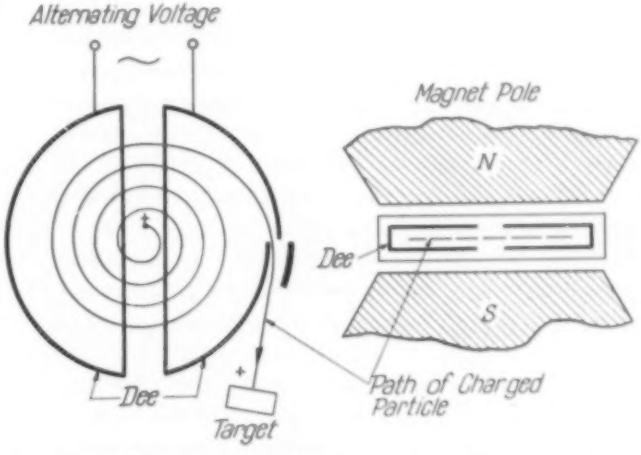


Fig. 5 — To Illustrate the Principle of the Cyclotron for Accelerating Charged Particles (Usually Protons or Deuterons) to the High Speeds They Must Have in Order to Penetrate Atomic Nuclei. The charged particles start near the center of the pair of half-pillbox "Dees" and travel in semicircles, always arriving at the gap at the right time to be accelerated by the alternating field between the Dees. Each semicircular path is larger than the one before, and the particles finally emerge from the edge of the Dees with enough energy to transform nuclei in the target material. To make the particles move in semicircles a magnetic field is necessary

charge, has an obvious advantage over a charged particle (such as a proton) for penetrating a nucleus, for it can get into the nucleus without being hindered by the orbital electrons and slowed down or repelled by the nuclear charge.

Artificial Radioactivity In 1934 it was found that the transformations of nuclei are not always completed right after the incident particle hits its target nucleus. In many experiments the target nucleus, after ejecting one or more particles or making whatever other adjustments are necessary at the instant of impact, finds itself still in an unstable state and later has to make some further internal alterations before reaching permanent stability. The usual trouble with the first-formed or intermediate nucleus is that it has one too many protons or one too many neutrons. This fault is usually repaired, curiously enough, not by throwing out the extra heavy particle, but by converting it into one of the other kind! An extra proton in the nucleus changes into a neutron either by ejecting its electrical charge as a positive electron (symbol: $_{1}e^{0}$) or by capturing one of the orbital electrons in the atom and thus neutralizing the positive charge originally carried. If the nucleus happens to have an extra neutron for stability, this excess neutron changes into a proton by ejecting a negative electron ($_{-1}e^{0}$).

These delayed reactions occur at a rate that continually decreases with time. In fact the time schedule is similar to the one followed by the spontaneous changes among the natural radioactive elements, and these intermediate unstable nuclei are said to be "artificially radioactive". Some 500 different kinds of artificially radioactive nuclei have been made and studied, with half-life (the time after which half of the unstable nuclei originally present have made the change) ranging from a fraction of a second to thousands of years.

Tracer Atoms The artificially radioactive nucleus, while it is awaiting its final change, is, of course, a perfectly good nucleus for an atom. It surrounds itself with the right number of electrons to balance the charge of the nuclear protons, and the resulting atom shows all the chemical properties of other atoms having that nuclear charge, and can form all the oxides, sulphides or other chemical compounds of a stable element. For example, if the nucleus contains 30 protons the atom is a zinc atom. Mixed in with other zinc atoms, it follows along with them in all their chemical or metallurgical changes until the instant comes for its nucleus to change. The location of the atom at this time can be determined by detecting the fast particle or the radiation the nucleus emits while changing. Such "tracer atoms" have been used to study self-diffusion in metals, as well as other problems in physics, chemistry and biology.

Uranium Fission At the beginning of 1939 the prospects for producing atomic power in useful quantities looked, in view of all the experience with atom-smashing, rather dim. The energy was there, certainly. It could be released — and frequently had been released — by changing one kind of nucleus into another. True, all the changes that had been effected were changes involving the addition or subtraction of only a few neutrons or protons, and the energies per particle that had been realized in these changes — while conforming to theory — were far short of the energy that, it was calculated, would be freed if medium-mass nuclei could be made either by putting together light nuclei or by breaking up heavy nuclei.

Nevertheless, the energies that had been measured were impressive enough, when compared with the energy yields from ordinary chemical reactions. The basic trouble was the lack of an efficient method for causing the nuclear transformations. The nucleus had to be struck by some projectile, and to get each projectile ready and on its way took many times as much energy as the nucleus released when it was struck. The thing was worth doing on a small scale, for information, but as a power source the nucleus had not yet shown any signs of paying its own way. The auxiliary equipment absorbed more energy than the main engine produced.

Early in 1939 this picture changed abruptly. It was found that a uranium nucleus when struck by a neutron sometimes breaks into two medium-sized nuclei, releasing the huge quantity of energy that such a disintegration would be expected to yield. Furthermore — and even more important for the self-generating atomic-power problem — the nucleus in splitting throws out some free high-speed neutrons which may themselves cause the splitting of other uranium nuclei — a so-called chain reaction. This breaking up of a heavy nucleus into two approximately equal halves soon came to be known as "fission".

Chance of a Chain Reaction The vital importance of the new neutrons set free in a fission can be appreciated by considering again the combination of oxygen and hydrogen to form water vapor, in an oxy-hydrogen flame or in an exploding mixture. This process, like any other self-sustaining reaction,

is a "chain reaction". On the average, every water molecule when it forms must prepare the way, by breaking up molecules of the unreacted gas, for the formation of at least one other water molecule — otherwise the oxygen molecules and hydrogen molecules will mingle as strangers not interested in each other. If the formation of each water molecule leads, on the average, to the formation of more than one additional water molecule, the reaction goes explosively in an avalanche. If it leads to the formation of just one additional water molecule the reaction proceeds at a constant rate — it is usually easy to control conditions, as they are controlled in a flame, for example, so that this happens. But if each water molecule has, on the average, less than one offspring the race soon dies out and the reaction stops.

This principle, that only chain reactions are self-sustaining, applies in nuclear chemistry as well as elsewhere. If the fission process was to be a self-maintained source of power, each fission must (on the average) yield enough neutrons to cause at least one additional fission. Could such a chain reaction be realized? In 1939 no one knew for certain, and it was no easy task to find out. There were many considerations which indicated that the chain reaction on uranium could indeed be realized, and practically no direct evidence that it could not. On the basis of faith the research was started. Not until late 1942, two years after the subject had been removed from public view, was the question definitely answered to those directing the work, and the answer was first announced to the world nearly three years later by the explosion in Hiroshima.

The Status of the Problem in 1940

By the middle of 1940, 18 months after the discovery of fission, many experiments with this new effect had been made and much information about it had accumulated. The central question, whether a self-sustaining chain reaction would work, was still open, but it was possible to estimate roughly the chance that it would, and the chance did not look hopelessly small. The conditions under which the reaction would be most likely to go, if it went at all, could be predicted qualitatively. It was fairly clear what further experiments would have to be made before one could say whether the thing would work at all. Finally, the importance of the reaction for power production and for military purposes, if the reaction were possible, could be assessed.

In the following paragraphs we review the state of knowledge in June of 1940, with some discussion of the speculations that this knowledge had suggested. It is to be remembered that the factual information was public property throughout the world — the censorship on publication in this field was only just beginning.

Fission in Three Known Elements It was known that fission by neutron impact occurs in the three elements uranium, protoactinium and thorium. Of these, protoactinium is so scarce in nature that it could immediately be ruled out as a possible source of atomic energy in any quantity. Uranium, in which the effect was first discovered, is relatively plentiful, the estimate being about four parts per million in the earth's crust. Thorium is estimated to be three times as plentiful as uranium; on the other hand, it has no apparent advantage over uranium. The work has, in fact, been concentrated on uranium.

Fast Neutrons and Thermal Neutrons It was known that fission in thorium and protoactinium is caused by fast neutrons, thousands of times as fast as the molecules of air travel due to their heat at ordinary temperatures. In the case of uranium there is a difference between the two isotopes that are present in significant concentrations. This would be expected and was proved at an early date. The lighter nucleus, $_{92}U^{235}$, though it can be made to fission by fast neutrons, is far more susceptible to so-called thermal neutrons, neutrons so slow that in bouncing about among nuclei of a material at room temperature they neither gain nor lose speed, on the average. The heavier nucleus, $_{92}U^{238}$, is not fissionable by thermal neutrons; however, when a neutron with speed approximately a hundred times the thermal speed hits a $_{92}U^{238}$ nucleus it is very likely to be absorbed, changing the nucleus to $_{92}U^{239}$. This absorption of vagrant neutrons would obviously be a serious obstacle to the achievement of a chain reaction in natural uranium, wherein the heavy nucleus, it will be recalled, is 140 times as abundant as the light one. If a chain reaction was to go forward in this natural mixture the high-speed neutrons emitted in the fission of a $_{92}U^{235}$ nucleus would have to be slowed down to thermal speeds by collisions with other nuclei before they would be very apt to cause fission of further $_{92}U^{235}$ nuclei, and it was a grave question what fraction of them could be slowed down to thermal speeds without being lost at the intermediate speeds by absorption in the $_{92}U^{238}$.

On the favorable side, it was known that a *fast* neutron bouncing about among $_{92}U^{238}$ nuclei

loses energy by stirring up the nuclei ("inelastic collisions") without being absorbed by them.

One to Three Neutrons Per Fission The number of fast neutrons emitted per fission was known to lie between one and three. All the hope for the project was based on this crucial fact. If the average fission yielded less than one neutron, fissions could never reproduce themselves in a self-sustaining or multiplying chain reaction; but with a yield greater than one there was a possibility that conditions might be so arranged that at least one neutron from the average fission would avoid all the pitfalls while it slowed down and it could finally reach another $_{92}U^{235}$ nucleus with the right speed to cause another fission. The known upper limit of three fast neutrons per fission was a sobering datum. With so few to start with, every precaution would have to be taken against losing neutrons by non-fission processes. The bare possibility of a chain reaction was there, certainly, but at best it would take some skillful managing to make it go, and there was no certainty that it could be achieved.

The Fission Products It was also known in 1940 that the products of fission of a $_{92}U^{235}$ nucleus, in addition to the few fast neutrons that are so important, are a pair of unstable nuclei, each one accounting for roughly half the particles (protons and neutrons) contained by the original uranium nucleus. These newly born nuclei, containing too many protons or too many neutrons for stability, change radioactively through various stages until they finally become stable medium-mass isotopes of elements near the middle of the periodic table. It was recognized that the fast particles and radiations emitted in the fission and in these subsequent changes (and escaping from the mass) would be hazardous to health, and that protection against them would be needed if an atomic-power plant using uranium fission were ever constructed. It was expected, moreover, that at least some of these product nuclei would be very likely to absorb neutrons of various speeds and that a chain reaction, if it were once started, might well be halted by the accumulation of neutron-absorbing products long before the supply of fissionable nuclei was seriously depleted.

The Energy of Fission The total energy set free in each fission was known to be approximately 200 million electron volts. This meant, in more everyday terms, that when all the atoms in 1 lb. of $_{92}U^{235}$ nuclei had undergone fission a total of 10,000,000 kw-hr. of energy would have been released. To generate this quantity of energy by burning coal, about 1250 tons of coal would be required; to release it by exploding TNT would need approximately 10,000 tons of TNT. Evidently the chain reaction, if it could be achieved, had tremendous promise both for productive and for military uses.

The Prospects in 1940

In 1940 there was wide divergence of opinion among responsible scientists as to whether the chain reaction could or could not be realized, but there was general agreement that the answer would be well worth finding out. There was general agreement, moreover, in view of the wars expanding in Europe and Asia, that it would be foolhardy to make the results of such researches freely available to the world at large. The censorship of publications in the field of fission and related subjects, at first on a voluntary basis, started in 1940.*

The secret work of the next five years, though it grew in size and complexity beyond all forecasting, was in its main lines a development of ideas that were fairly well-defined at the start. It will help, in reviewing the various phases of the project, to have in mind what problems were outstanding in 1940 and what means were thought most likely to solve them.

Neutron Losses A chain reaction, with every fission of a U-235 nucleus giving rise on the average to at least one other fission, was desired. The average fission gives more than one neutron, but not all can be effective for causing another fission because any fast neutron set free in a fission would have one or another of the following four possible fates:

1. It might fly clear out of the uranium mass and be lost by absorption in the surrounding material.

2. It might be absorbed by the nucleus of some impurity atom in the uranium or other materials present.

3. It might be absorbed by one of the much more numerous U-238 nuclei. The chances are that the neutron would make 140 collisions with U-238 nuclei for every collision with a U-235 nucleus; the loss by this process would therefore be expected to be a major one.

4. It might be absorbed by a U-235 nucleus and produce another fission. This was the only

*A sprightly account of the espionage and counter-espionage that shielded the project for four years was printed in *The New Yorker* for Oct. 27, 1945.

desirable alternative of the four, and the chain reaction could not occur unless the competition from the other three processes could be made sufficiently small.

The Critical Size Alternative (1), loss by escape, would be certain to happen to nearly all the neutrons if the lump of intended reactant was very small; it would also happen to approximately half the neutrons set free near the surface, no matter how big the lump. But if enough uranium were got together so that the average neutron set free somewhere in it would have only a small chance of getting outside before being slowed down to thermal speeds, this loss of neutrons by escape could be made small in comparison with the other alternatives. (Remember that even an assemblage of a billion atoms is largely space — in comparison with the "size" of a nucleus — so a neutron can travel a comparatively long way before it collides with something "solid".) It would be best to shape the uranium in some compact geometrical form — ideally, a sphere — to contain the volume in as small a surface as possible. There might also be some advantage in enclosing the uranium in a thick layer of material whose nuclei would tend to bounce the neutrons back into the uranium without capturing them or letting them through.

At the best, however, if the chain reaction was to go at all, the reacting mass would have to be bigger than a certain critical size. The questions were: Would *any* size be big enough? Would the critical size be impracticably large? What tricks could be done with materials, arrangements and neutron-reflecting envelopes to make the critical size as small as possible?

Impurities As for alternative (2), it was known that certain nuclei if present as impurities to the extent of only a few parts per million would soak up so many neutrons as to make a chain reaction impossible. The problem of getting rid of all such impurities to the last trace was certain to be a big one.

Isotope Separation The obvious way of combatting alternative (3), non-fission capture by U-238 nuclei, would be to pick the U-235 atoms out of the mixture of isotopes and discard the U-238. The free neutrons in a mass of separated U-235, bouncing only from one U-235 nucleus to another, would have a fair chance of being absorbed and causing fissions even before they were slowed to thermal speeds.

Unfortunately, the separation of isotopes looked to be (and proved to be) no easy job. It had been done by several investigators, but only in barely microscopic quantities for experimental use. Perhaps it could be done on a large scale, but mammoth plants would be required at best, and in 1940 there was no certainty that any one of the known methods of isotope separation could be adapted to large-scale operation. Five years later, as it turned out, two of these methods had been developed to the necessary degree and were yielding large quantities of separated U-235. In 1940, however, there was no choice but to see what could be done with the natural mixture of isotopes, where a free neutron hits 140 nuclei of U-238 for every one of U-235.

Use of a Moderator The simplest procedure, in principle, would have been to accumulate a large number of pieces of pure uranium metal and see whether, when these were piled together, a self-sustaining chain reaction would start when a certain size was reached. However, consideration of the details of what would go on in such a pile suggested several things that might be done to reduce the critical size — or rather, since it was not yet known whether *any* size would be big enough, to improve the chance that a chain reaction would occur.

For one thing, the fast neutrons emitted in a fission would have to be slowed down before they could be very effective in causing other fissions. (Remember that the slow moving neutrons are more effective in splitting U-235 than speedy ones.) It would be well to do this slowing-down in as small a space as possible, and well to do it with material unlikely to absorb the neutrons; very light nuclei, which would recoil rapidly from the impact of neutrons and absorb much kinetic energy per collision, would be best for the purpose.

The idea of diluting the uranium with some light-nucleus material (called a "moderator") to help slow down the neutrons could be examined theoretically, and it proved to be sound. The requirements for a moderator nucleus are that it should not absorb neutrons strongly, and that its mass should match the mass of the neutron as nearly as possible. The hydrogen nucleus, a single proton, would fill the latter requirement almost perfectly, but the other consideration made the deuterium nucleus with one proton and one neutron seem a better choice. Either hydrogen or deuterium might be used (even when combined with oxygen as water or heavy water). The use of helium, a permanent inert gas, would clearly present some serious practical difficulties. Lithium and boron are unusable because of their

high neutron absorption. Beryllium and carbon would both be possibilities.

So the list of materials to consider for a moderator was fairly limited — it came down to water, heavy water, beryllium and carbon.

Use of a Lattice Assuming that a moderator would be used, it did not follow that a homogeneous mixture of uranium and moderator atoms would be the best arrangement. In fact, considering that the free neutrons are in greatest danger of being absorbed uselessly by U-238 nuclei while they are slowing down through a certain range of speeds above the thermal range, it appeared that neutrons could be conserved by letting them leave the uranium while still at high speed, slow themselves down by collisions in a moderator, and return to the uranium only after their speed had fallen so low that fission-capture in U-235 would be much more likely than non-fission capture in U-238. A lattice arrangement, with lumps of solid uranium imbedded in a matrix of pure moderator material, seemed to be the nearest practicable approach to this ideal situation.

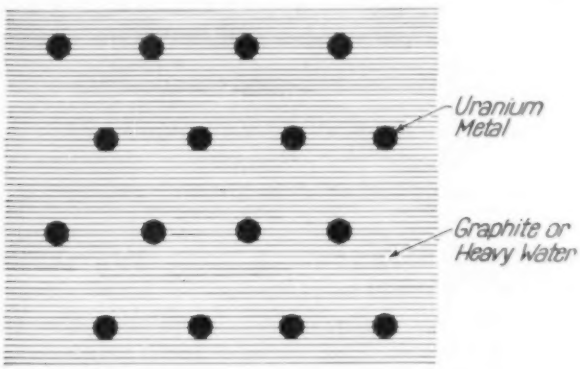


Fig. 6 — Principle of the Lattice Moderator Method for Getting a Self-Sustained Chain Reaction With the Normal Mixture of Uranium Isotopes. Each slug of uranium shoots fast neutrons, set free by fission, into the moderator around it and receives slow neutrons, suitable for causing other fissions, from the moderator

How big should the lumps be? How far apart? In what geometrical arrangement? With the optimum choice for all these variables, what would be the critical size?

The answers to such questions of design could be calculated, subject to wide uncertainties. (The available data concerning the interactions of neutrons and nuclei were none too accurate.) It was possible, moreover, to improve the accuracy of these data by doing some small-scale and intermediate-scale experiments.

The Question of Materials The most optimistic estimates of the critical size indicated that *tons* of pure uranium and *tons* of pure moderator would be needed, yet by 1940 only a few ounces of metallic uranium, of doubtful purity, had ever been produced in this country! Deuterium, perhaps the most desirable of the possible moderators, had been separated from the ordinary hydrogen isotope, which is 5000 times as abundant, in enough quantity to make a few quarts of heavy water for experimental use, but there was no bright prospect of pushing the output, from any known separation method, up to the scale of tons. Beryllium was being widely used as an alloying agent, but only 700 lb. of the metal itself were produced in 1940 in the United States. Carbon in the form of graphite was being made in great bulk, of course, but whether tons of it could ever be available with the required purity was an open question. Even if there were a certainty that the chain reaction could be made to go, to get the materials for it would clearly require starting a large industry almost from scratch.

To summarize: In 1940, fission of uranium in a self-perpetuating chain reaction was seen to be a goal of tremendous importance, surrounded by tremendous obstacles, and perhaps not ever attainable — even in principle.

The Chain Reaction Works!

We pass over two and a half years filled with experiments and calculations, with occasions for elation and for despondency, with organizations and reorganizations and continual expansion of effort, and come to December 2, 1942.

The scene is a squash court at the University of Chicago. The object of interest is a flattened spheroidal pile of graphite blocks, supported in a wooden framework, resembling in some degree a mammoth door knob. Within this pile, spaced among the graphite blocks so as to form a cubic lattice, are lumps of uranium metal — six tons of metal — and other lumps of uranium oxide. Through the pile near its center run three channels each containing a rod of cadmium. Imbedded in the pile and distributed around it are various detectors for measuring the flux of free neutrons and the rate at which fission is occurring.

Two of the cadmium rods are pulled out completely, and the third is then slowly withdrawn. When it is part way out the detectors show that the number of fissions per second in the pile is increasing rapidly, actually in runaway fashion. It proves possible, by slight in-and-out movements of the cadmium rod about

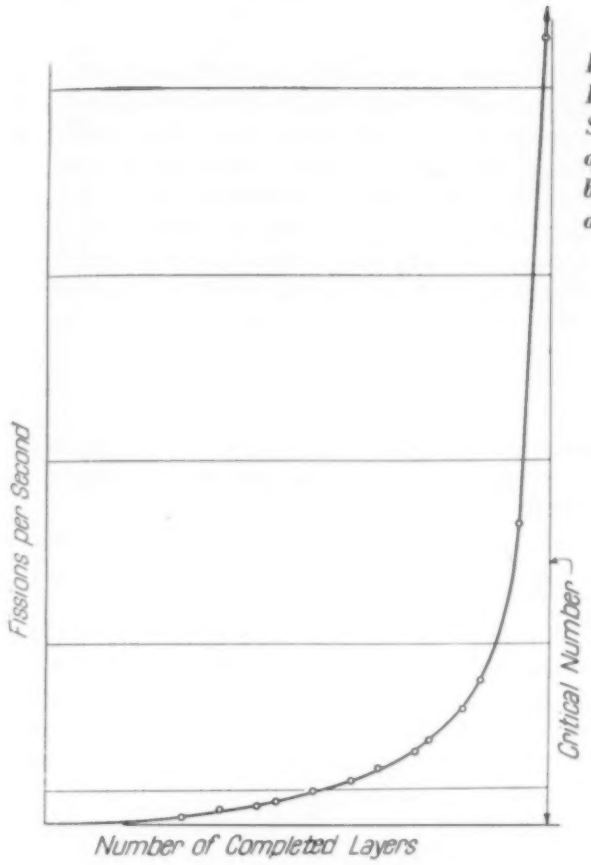


Fig. 7 — Showing How the First Self-Sustained Chain-Reacting Graphite-Uranium Pile Approached Its Critical Size. After completion of a certain number of layers of graphite blocks and uranium slugs, the reaction could be kept from running away only by use of neutron-absorbing control rods. (Adapted from the Smyth Report)

this critical position, to stabilize the rate of fission at any desired level. The thing is the first one of its kind ever initiated by man: A self-sustaining nuclear chain reaction!

The energy produced by this first pile was minuscule — for the first ten days it was permitted to generate ½ watt or less, and thereafter it was run at 200 watts. The heat equivalent of the energy liberated was so little that it could not easily be measured directly; it was more convenient to compute it from the measured number of U-235 fissions per second. However, this first pile was an answer of the most concrete and undeniable sort to many of the questions that had been debated since the discovery of the fission effect: A chain reaction could be achieved with the normal mixture of uranium isotopes; the critical size, if the uranium was associated with a suitable moderator in a suitable lattice array, was not unmanageably large; and the reaction was easily controllable. The data and calculations basic to the design of this first pile were confirmed by its success and could be used with assurance in the design of later piles. (Actually, the critical size allowed for in the design had been a little too generous, and the pile had had to be flattened off when the measurements during its assembly showed that the intended full-sphere would be too big.) Finally, the pile itself was available as a useful tool for further experiments.

Control The question of control is one which has not yet been discussed in this article. So long as there was serious doubt that a chain reaction could be initiated, worries over how to control it would have been premature, but as the early tests and figures placed the prospect in a more and more favorable light the question became pertinent and pressing.

In any chain reaction, if the process is to go at a constant rate there must be some mechanism which keeps the reproduction factor, the average number of new reactions produced in consequence of a single reaction, *exactly* equal to one. If it is less than one the process soon plays out to a halt; if it is more than one the process runs away. In many of the familiar chemical chain reactions, such as the burning of an oxy-hydrogen flame or the burning of coal in air, the process is automatically limited by the rate at which the inert products are got out of the way and replaced by fresh reactants.

For the fission reaction, it was originally expected that Nature might take care of the matter unaided; as the reaction proceeded the mass would become hotter, the average speed of the thermal neutrons would go up, their chances of causing fission in the U-235 nuclei would correspondingly go down, and stability would automatically be reached at some temperature and some corresponding rate of fission. It was recognized that in principle the reaction might be controlled all the way down to a zero rate by placing in the mass some movable strips or rods of cadmium or boron steel or other strong neutron-absorber, and adjusting these strips so as to keep the flux of free neutrons at any desired level. As a practical matter, it was not certain that the reaction would not start and run away faster than the controls could be manipulated to keep it in check, in view of the speed of the neutrons.

Delayed Neutrons Such fears, as the matter turned out, were ungrounded. Very conveniently, it was discovered, the neutrons from a fission are not always all emitted at the instant the incident neutron strikes the U-235 nucleus; on the average, 1% of them are delayed by at least 0.01 sec., and approximately seven out of every 10,000 are delayed by at least 1 min. This means that if the control rods are

pulled out a little too far, so that the reaction can run away, it runs away not immediately but gradually, as the delayed neutrons build up in concentration. The times involved are longer the lower the power level at which the pile is operating, but even at a high power level they are long enough to permit easy control by movable rods. The control can, in fact, be entirely automatic, with a neutron detector in the pile to measure the flux of free neutrons and govern the adjustment of the rods to keep this flux at the desired constant value.

It will be noted that the construction of this first pile embodied the general principles that had been recognized in 1940 — namely, the use of a moderator to help slow down the neutrons without capturing them, and the use of a lattice arrangement to help save the neutrons from nonfission capture by U-238 nuclei while they are slowing down through the critical range of speeds where such capture is highly probable. The story of how the materials, almost totally lacking in 1940, had been got together will be summarized later. Obviously, by the end of 1942 enough graphite of adequate purity, and enough uranium in the form of metal and oxide, had been accumulated to make an operating example of a self-maintained fission reaction.

The thing would work! How was it to be used?

The Chain Reaction as a Weapon for War

THE time, remember, was December 1942, a year after the attack on Pearl Harbor. The important thing, in the midst of a war, was to exploit the fission process not as a source of controlled power but as a military explosive. The destructiveness of an atomic bomb, if one could be made, was a matter for estimate, and it appeared likely that atomic bombs might well be decisive weapons, capable of winning the war quickly for whichever side first succeeded in making them. The Germans, of course, had known as much as we did about the problem in 1940 — in fact, fission had first been discovered in Germany. It was certain that our enemies were actively working on it. In Norway they controlled the only plant in the world for separating deuterium on a large scale, and they had ordered large quantities of deuterium-containing paraffin to be made. There was no known use for large quantities of this compound except in connection with the uranium problem.

Bombs and Fast Neutrons The chain reaction in normal graphite, it was understood, could hardly be expected to serve directly for a bomb. The time required for the fast neutrons to slow down to thermal speeds, short as it is, is too long. In such an interval the atoms of uranium and graphite in the uncontrolled reaction would be thrown far apart, so that most of the neutrons would be wasted by escape and most of the fissionable nuclei would be dispersed unfissioned. An atomic bomb, like TNT or any other chain-reaction explosive, cannot make efficient use of the energy latent in it unless the reaction goes so quickly that the material does not have time to get spread far apart before a sizable share of the energy is released. For an atomic bomb, this means that the fission must be done with fast neutrons.

Now it was known that fast neutrons would cause fission in U-235, though with a lower probability per collision than thermal neutrons. Of course the rate of the fast-neutron fission process could be increased most readily by providing nothing but U-235 nuclei for the fast neutrons to hit. It was expected that if enough U-235 atoms could be separated from the U-238 atoms and could be brought together rapidly in one place an efficient explosive chain reaction with fast neutrons would occur. The critical size for a lump of pure U-235 was estimated to be somewhere between two and 200 lb. The energy released by such a bomb would be as much as the energy released in exploding many *thousand tons* of TNT! The military effects of such an explosion could be prophesied in detail only by the experts, but it was obvious to anyone that there would be destruction on a vast scale.

It was these considerations that had spurred the effort to develop methods for separating the uranium isotopes in quantity, and had justified the expansion of this effort even after it became clear that the slow-neutron chain reaction would succeed in the unseparated mixture.

Uranium Piles to Make Plutonium Even in 1940, however, another possibility for an atomic explosive was seen, at first dimly, and then more and more clearly as experiments were carried out to test the original idea. By December of 1942, when a controlled chain reaction in a pile of unseparated uranium and graphite had been demonstrated, the immediate future for such piles was already planned. More of them would be built, much

bigger and much more powerful. The energy they released would be thrown away, somehow; no attempt would be made to harness it. Instead, the piles would be used solely as factories for making a fission-explosive material similar to U-235, and this explosive material would finally be used for atomic bombs.

This new explosive material has not figured in our discussion hitherto, because it is an incidental by-product of the chain reaction in the graphite-uranium pile and not an essential ingredient of this reaction. What happens is this: Some of the neutrons, especially those in a certain range of speeds, are absorbed by U-238 nuclei. (It will be recalled that the moderator and the lattice structure were devised to keep this absorption by U-238 from soaking up too large a fraction of the free neutrons.) Capture of a neutron converts the U-238 nucleus to U-239. This nucleus is unstable; it soon changes one of its neutrons into a positively charged proton by somehow shooting off a negative electron, and thus becomes the nucleus of a new chemical element, called "neptunium". This nucleus, $_{93}Np^{239}$, still has too many neutrons for stability, and soon emits another electron to change another neutron into a proton. The resulting nucleus then contains 94 protons; it is the nucleus of another new chemical element, called "plutonium"; its symbol is $_{94}Pu^{239}$.

The plutonium nucleus is not entirely stable — like all the other nuclei containing more than 83 protons it is naturally radioactive, and it is in fact subject to spontaneous change with ejection of an alpha particle — but its natural life expectancy is so long that for practical purposes it can be regarded as a permanent nucleus. The reactions leading to it can be summarized in the shorthand notation as follows:

$$_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239}$$
$$_{92}U^{239} \rightarrow {}_{93}Np^{239} + {}_{-1}e^{0}$$
$$_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{-1}e^{0}$$

The importance of plutonium for the atomic bomb project arises from two facts: *(a)* Like U-235, it is caused to fission by neutron impact, and *(b)* it is a different element, chemically, from the uranium in which it is formed. The first fact means that plutonium may be suitable for an atomic bomb; the second means that it can be removed from the surrounding atoms and concentrated by chemical methods much more readily than the rare U-235 isotope can be separated from its chemical twin U-238.

Even in 1940 it was surmised on theoretical grounds that plutonium would be formed, that it would be practically stable, and that it would have fission properties similar to those of U-235. These surmises were soon confirmed by experiment. By the end of 1942 the manufacture of plutonium in a chain-reacting pile and its separation by chemical means from the uranium was a well-defined possibility. For a year or more, in fact, this possibility had been recognized as the chief and urgent reason for wishing to realize the chain reaction.

Already much had been learned from small-scale — even microscopic — experiments not only about the nuclear properties of the new element plutonium, but also about its chemistry. A sample of the stuff — not the $_{94}Pu^{239}$ expected from the pile reaction, but its isotope $_{94}Pu^{238}$ — had been made by bombarding uranium with high-speed deuterons accelerated in a cyclotron, the sequence of events being:

$$_{92}U^{238} + {}_{1}H^{2} \rightarrow {}_{93}Np^{238} + 2{}_{0}n^{1}$$
$$_{93}Np^{238} \rightarrow {}_{94}Pu^{238} + {}_{-1}e^{0}$$

This sample, though smaller than the head of a pin, had been large enough for the micro-chemists to study thoroughly. They had found that plutonium, though generally like uranium itself in its chemical properties, has certain peculiarities of its own which would make it separable from uranium and the various fission products in the pile, and by December 1942 the chemists on the project understood fairly well how to set about the job of extracting traces of plutonium from a large quantity of uranium mixed with various medium-mass fission products.

The proposal, then, was to build giant chain-reacting piles, feed uranium into them, let the reaction proceed until a worthwhile concentration of plutonium had built up, remove the metal, extract and purify the plutonium, and find out how to use plutonium efficiently in a fast-neutron-fission atomic bomb — all this to be done before the enemy's efforts to make atomic bombs, however he might be going about it, had succeeded.

Size of Factory Needed The magnitude of the venture is evident from some simple considerations: If the critical size of a Pu-239 bomb is between two and 200 lb., as the estimates for U-235 indicated, a production in the neighborhood of 2 lb. of plutonium per day would seem to be a reasonable requirement. What would be the energy balance for such an operation?

One of the neutrons from each U-235 fission, on the average, has to be used up in another fission in order to keep the chain reaction going. Some of the remaining neutrons would be absorbed in various impurities and in the neces-

An Oath for Scientists and Engineers

An Editorial★

THE ATOMIC BOMB is a frightening thing, not because we are afraid of what we can do with it, but because we are afraid of what an enemy could do with it. It does not frighten us that the English and the Canadians share fully our knowledge because we trust them. They also trust us. We would share fully our knowledge of life and death, even, with any people that we trusted, and in turn trusted us. Mutual trust is essential.

Man is not afraid of the truth; he is not afraid of what he knows. He *is* afraid of what he doesn't know. His suspicions breed fear. Hence the paramount necessity of the freest interchange of ideas. In such an important thing as war-making ability he instinctively feels that censorship means that something is going on that bodes no good to him and therefore must be hid. That goes for the "foreigner's" view of the Anglo-Saxons, also.

Whom can we trust?

While the use of an atomic bomb can be determined by politicians, diplomats and militarists, either sane or insane, high-minded or ambitious, its manufacture and further perfection depend on engineers and scientists. Here enter a new field of human endeavor and another class of human beings. Successful engineers and scientists, men competent to make and perfect atomic bombs are men of truth. Men of truth perforce, for a lie never built a safe bridge, discovered a mathematical formula, deduced a physical principle, or synthesized a new chemical. Engineers and scientists *must* know the truth, accept the truth, use the truth.

In such a group of men, including *all* nationalities, is our present hope that civilization — humanity even — can withstand the atomic blast. If the politicians, diplomats and militarists cannot devise some means of free interchange of the truth about atomic energy, at least the engineers and scientists can proceed on their own. They can meet internationally and open their proceedings by swearing to a new Hippocratic oath:

> **"As a trained scientist or engineer, I acknowledge my profound belief that the laws of Nature operate for all mankind, irrespective of nationality, creed or color, and I am therefore in duty bound to share my searches and discoveries in atomic energy freely with all others, by word of mouth, writings, publications, and visitations, and that this paramount duty to Mankind transcends any lesser loyalty whatever."**

No scientist or engineer who swore to that oath would submit to censorship no matter how specious, nor could he work in a secret laboratory devising bigger and better atomic bombs. Even in Nazi Germany there would be enough brave lovers of truth and humanity to bring out the news before these horrible things could be secretly perfected.

★This editorial was written by the Editor of Metal Progress and represents his views. It is not an official pronouncement of The American Society for Metals.

sary structural members in the pile. Some would escape. Assuming that fewer than three neutrons are set free in the average fission, it could be expected that considerably less than two neutrons per fission could be spared for absorption in U-238 to produce Pu-239.

On this basis it would be necessary to have fission occur in rather more than 1 lb. of U-235 nuclei per day in order to produce 2 lb. of Pu-239 per day.

Fission of 1 lb. of U-235 is known to liberate approximately 10,000,000 kw-hr. (10 million) of energy; averaged over a 24-hr. day this dissipation amounts to nearly 500,000 kw. This is the crudest kind of estimate, of course — the dissipation might have to be much more, but it could scarcely be many-fold less. Smyth allows that between 500,000 and 1,500,000 kw. would be a reasonable guess for a plant producing 1 kg. (2.2 lb.) of plutonium per day. For comparison, the ultimate capacity of the hydro-electric power plants at Grand Coulee Dam is expected to be 2,000,000 kw.

The prototype for this proposed plant, the only working example of a uranium-graphite chain-reaction plutonium factory in existence at the beginning of 1943, was operating at a level of 0.2 kw., producing plutonium at a rate which would yield enough for a military bomb in something over 70,000 years!

There was no possibility, of course, of merely scaling up this first pile by a factor of several million; the production piles would have to be designed essentially from scratch. Actually, in anticipation of the success of the first pile, such problems as could be foreseen in the design of a production plant were already being studied in 1942, even before the first pile was assembled.

Supply of Uranium As to one central problem, the supply of pure uranium metal as raw material for the factory, some quotations★ from the Smyth Report will tell the story. Reviewing the situation in 1940 (Chapter II):

"Deposits of uranium ore are known to exist in Colorado, in the Great Bear Lake region of northern Canada, in Joachimstal in Czechoslovakia, and in the Belgian Congo. Many other deposits of uranium ore are known, but their extent is in many cases unexplored. Uranium is always found with

★From here on, wordage in quotations is a verbatim copy from the Smyth Report.

Official Declaration About Atomic Energy

THE PRESIDENT of the United States, the Prime Minister of the United Kingdom, and the Prime Minister of Canada issued the following statement on November 15, 1945:

ONE — We recognize that the application of recent scientific discoveries to the methods and practice of war has placed at the disposal of mankind means of destruction hitherto unknown, against which there can be no adequate military defense, and in the employment of which no single nation can in fact have a monopoly.

TWO — We desire to emphasize that the responsibility for devising means to insure that the new discoveries shall be used for the benefit of mankind, instead of as a means of destruction, rests not on our nations alone, but upon the whole civilized world. Nevertheless, the progress that we have made in the development and use of atomic energy demands that we take an initiative in the matter, and we have accordingly met together to consider the possibility of international action:

(a) To prevent the use of atomic energy for destructive purposes.

(b) To promote the use of recent and future advances in scientific knowledge, particularly in the utilization of atomic energy, for peaceful and humanitarian ends.

THREE — We are aware that the only complete protection for the civilized world from the destructive use of scientific knowledge lies in the prevention of war. No system of safeguards that can be devised will of itself provide an effective guarantee against production of atomic weapons by a nation bent on aggression. Nor can we ignore the possibility of the development of other weapons, or of new methods of warfare, which may constitute as great a threat to civilization as the military use of atomic energy.

FOUR — Representing, as we do, the three countries which possess the knowledge essential to the use of atomic energy, we declare at the outset our willingness, as a first contribution, to proceed with the exchange of fundamental scientific information and the interchange of scientists and scientific literature for peaceful ends with any nation that will fully reciprocate.

FIVE — We believe that the fruits of scientific research should be made available to all nations, and that freedom of investigation and free interchange of ideas are essential to the progress of knowledge. In pursuance of this policy, the basic scientific information essential to the development of atomic energy for peaceful purposes has already been made available to the world. It is our intention that all further information of this character that may become available from time to time shall be similarly treated. We trust that other nations will adopt the same policy, thereby creating an atmosphere of reciprocal confidence in which political agreement and cooperation will flourish.

SIX — We have considered the question of the disclosure of detailed information concerning the practical industrial application of atomic energy. The military exploitation of atomic energy depends, in large part, upon the same methods and processes as would be required for industrial uses.

We are not convinced that the spreading of the specialized information regarding the practical application of atomic energy, before it is possible to devise effective, reciprocal, and enforceable safeguards acceptable to all nations, would contribute to a constructive solution of the problem of the atomic bomb. On the contrary, we think it might have the opposite effect. We are, however, prepared to share, on a reciprocal basis with others of the United Nations, detailed information concerning the practical industrial application of atomic energy just as soon as effective enforceable safeguards against its use for destructive purposes can be devised.

SEVEN — In order to attain the most effective means of entirely eliminating the use of atomic energy for destructive purposes and promoting its widest use for industrial and humanitarian purposes, we are of the opinion that at the earliest practicable date a commission should be set up under the United Nations Organization to prepare recommendations for submission to the organization. The commission should be instructed to proceed with the utmost dispatch and should be authorized to submit recommendations from time to time dealing with separate phases of its work.

In particular the commission should make specific proposals:

(a) For extending between all nations the exchange of basic scientific information for peaceful ends.

(b) For control of atomic energy to the extent necessary to ensure its use only for peaceful purposes.

(c) For the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction.

(d) For effective safeguards by way of inspection and other means to protect complying states against the hazards of violations and evasions.

EIGHT — The work of the commission should proceed by separate stages, the successful completion of each one of which will develop the necessary confidence of the world before the next stage is undertaken. Specifically it is considered that the commission might well devote its attention first to the wide exchange of scientists and scientific information, and as a second stage to the development of full knowledge concerning natural resources of raw materials.

NINE — Faced with the terrible realties of the application of science to destruction, every nation will realize more urgently than before the overwhelming need to maintain the rule of law among nations and to banish the scourge of war from the earth. This can only be brought about by giving wholehearted support to the United Nations Organization, and by consolidating and extending its authority, thus creating conditions of mutual trust in which all peoples will be free to devote themselves to the arts of peace.

It is our firm resolve to work without reservation to achieve these ends.

radium although in much larger quantity. Both are often found with vanadium ores. Small quantities of uranium oxide have been used for many years in the ceramics industry.....

"As has already been mentioned, little or no uranium metal had been produced up to 1940 and information was so scant that even the melting point was not known. (For example, the "Handbook of Physics and Chemistry" for 1943-1944 says only that the melting point is below 1850° C. whereas we now know it to be in the neighborhood of 1150° C.) Evidently, as far as uranium was concerned, there was no insurmountable difficulty as regards obtaining raw materials or producing the metal, but there were very grave questions as to how long it would take and how much it would cost to produce the necessary quantities of pure metal."

Later (Chapter VI):

"Obviously there would be no point in undertaking this whole project if it were not going to be possible to find enough uranium for producing the bombs. Early indications were favorable, and a careful survey made in November 1942 showed that immediate delivery could be made of adequate tonnages of uranium ores.

"At the end of 1941 the only uranium metal in existence was a few grams of good material made on an experimental basis by the Westinghouse Electric & Mfg. Co. and a few pounds of highly impure pyrophoric powder made by Metal Hydrides Co. The only considerable amount of raw material then available in this country was in the form of a commercial grade of black uranium oxide, which could be obtained in limited quantities from the Canadian Radium and Uranium Co. It contained 2 to 5% of impurities....

"By May 1942, deliveries averaging 15 tons a month of black oxide of higher purity and more uniform grade started coming in. Total impurities were less than 1%, boron comprised a few parts per million.....Deliveries of this material reached a ton a day in September 1942.

"Experiments at the National Bureau of Standards by J. L. Hoffman demonstrated that, by the use of an ether extraction method, all the impurities are removed by a single extraction of uranyl nitrate. The use of this method removed the great bulk of the difficulties in securing pure oxide and pure materials for the production of metal. Early in May 1942, arrangements were completed with the Mallinckrodt Chemical Works in St. Louis to put the new grade of oxide through an ether extraction process on a production basis for a further reduction in impurity content and to deliver the final product as brown dioxide. Deliveries started in July 1942 at a rate of 30 tons a month. This oxide is now used as a starting point for all metal production, and no higher degree of purity can be expected on a commercial scale. In fact, it was a remarkable achievement to have developed and put into production on a scale of the order of one ton a day a process for transforming grossly impure commercial oxide to oxide of a degree of purity seldom achieved even on a laboratory scale.

$1000 Cost Cut to $22

"The process which Westinghouse had been using to produce the metal was the electrolysis of KUF_5 at a cost of about $1000 per lb. Since the KUF_5 was produced photochemically under the action of sunlight this method constituted a potential bottleneck in production. It was found that uranium tetrafluoride could be used instead of KUF_5, and steps were taken to have this salt produced at the Harshaw Chemical Co. in Cleveland and at the du Pont plant in Penns Grove, N. J. Production started in August 1942 and by October 1942 was up to 700 lb. per day at Harshaw and 300 lb. per day at du Pont, the method of manufacture in both cases being the hydrofluorination of Mallinckrodt-purified dioxide.

"As the result of this supply of raw materials to Westinghouse, and as a result of plant expansion, deliveries had accumulated to a total of more than 6000 lb. by November 1942 and were expected to be at the rate of 500 lb. per day by January 1943. The purity of the metal was good, and the cost had dropped to $22 per lb.

"Deliveries of acceptable metal from Metal Hydrides Co. were delayed for various reasons and were just beginning in November 1942. This company's production was supposed to reach 1000 lb. per week thereafter.

"Neither the Westinghouse process nor the Metal Hydrides process was entirely satisfactory. Intensive activity designed to accelerate metal production, and carried out independently by F. H. Spedding and his associates at Iowa State College at Ames, Iowa, and by C. J. Rodden at the National Bureau of Standards, resulted in the development of a satisfactory method. Production facilities were set up at Ames in the fall of 1942 and had already produced more than one ton by the end of November. The process was extremely simple, rapid and low cost.

"Further research indicated additional changes that could be made to advantage, and by the middle of 1943 Spedding at Iowa and other producers who entered the picture were using the final production method adopted.

"By the end of 1942 arrangements had been

made by the Manhattan District to increase metal production by making greater use of the Mallinckrodt Chemical Works, the Union Carbide and Carbon Corp., and the du Pont Co.

"To summarize, almost no metal was available during most of 1942, a fact that seriously delayed progress, as we shall see, but the production problems had been nearly solved by the end of 1942 and some six tons of metal were incorporated in the pile built in November 1942. The whole problem of procurement of metal was taken over by the Manhattan District at the end of the year, under the general direction of Col. Ruhoff, formerly with the Mallinckrodt Chemical Works. From the point of view of the Metallurgical Project no further serious delays or difficulties have occurred because of metal shortages."

Moderator Materials For a moderator, deuterium combined with oxygen in the convenient compound heavy water would probably have been first choice. However, although much progress had been made with methods for separating the 0.02% of deuterium out of the natural mixture of hydrogen isotopes in the surface waters of the earth, it had become evident that several years would be required to make the quantities of heavy water needed for large-scale production piles. Beryllium, less advantageous as a moderator, seemed almost as difficult to get in the necessary quantity and purity. The choice was therefore narrowed down to the element carbon. New methods for purifying graphite were developed which succeeded in reducing the neutron absorption some 20% below that of the standard commercial materials. An adequate supply of this purified graphite was obtained from the National Carbon Co. and the Speer Carbon Co.

It is worth mentioning here, incidentally, that a small pile (generating 300 kw.) using heavy water as the moderator was built in 1944 for experimental purposes. Heavy water turned out to be even more advantageous than had been foreseen. With the uranium slugs in place, the self-maintaining chain reaction started when only three-fifths of the heavy water had been added, and it was necessary to take out some of the uranium and add extra control rods before filling the tank as planned. The critical size is much smaller than for a graphite pile. Some delayed nuclear reactions peculiar to deuterium cause the heavy-water pile to be rather slower in starting up and in stopping than a comparable graphite pile. In general, however, the operation has been according to expectation, and the pile has proved to be a useful laboratory tool.

Cooling The question of cooling was a major one. The first pile, radiating only 200 watts, had needed no auxiliary cooling system, but it would obviously be necessary to run the production piles at a high power level if any reasonably small quantity of uranium was to be tied up in the process and any reasonably large quantity of plutonium per day was to be produced. Cooling with helium gas seemed at first to be the best choice, and a pilot plant to operate at 1000 kw. with forced air or gas cooling was designed and built, but before its construction was well begun the decision was made that water would be, for various reasons including availability, a more satisfactory coolant for the production piles. There was no time to design and build a water-cooled pilot plant; all the problems incidental to water cooling had to be solved without benefit of pilot plant experience.

Plumbing The heat would be liberated chiefly in the uranium slugs, and the water would therefore have to be piped through the pile to the slugs. The pipes, in addition to meeting the usual requirements of being leak-proof, warp-proof and corrosion-proof, would have to pass two tests never before applied to any plumbing material: They would have to be poor absorbers of neutrons, and they would have to hold together even though their nuclei were being continually battered by the radiations at large in the pile.

Graphite pipes were not practicable. Seven other materials — lead, bismuth, beryllium, aluminum, magnesium, zinc and tin — would be satisfactory in that they would not soak up so many neutrons as to stop the chain reaction. Of these, beryllium tubing was not available, and of the other six metals, only aluminum seemed likely to be sufficiently corrosion resistant. There were serious doubts even about aluminum piping which were not dispelled until the plant had been in actual operation for some time.

Canning The cooling water could not be flowed directly in contact with the uranium slugs because of the danger of corroding the uranium and contaminating the water with dissolved radioactive fission products. On the other hand, any protective layer over the slugs would have to be watertight, corrosion-proof, low in neutron absorption, stable against neutron bombardment and radiation effects, and so thin and so close against the uranium that the heat transfer would be efficient. Since failure of the coating layer on any single slug might shut down the whole pile, it would be highly important to get a dependable coating.

Electroplating, hot-dipping, cementation-coating, corrosion-resistant alloys of uranium, and mechanical jacketing were all tried experimentally. The final choice was a thin jacket or can of aluminum, bonded uniformly to the uranium for good heat conduction and sealed gas-tight. This "canning" problem, simple as it sounds, turned out to be one of the most difficult technical problems in the whole project. Smyth writes: "On periodic visits to Chicago the writer could roughly estimate the state of the canning problem by the atmosphere of gloom or joy to be found around the laboratory." It was finally solved satisfactorily only after the first production pile had begun operation.

Loading and Unloading To tear the piles down periodically to remove the processed uranium slugs would be unthinkably inconvenient. The piles would have to be constructed so that the fresh slugs could be pushed into the graphite matrix and the processed slugs could be pushed out. A set of long parallel channels through the pile, with slugs pushed in at one end and pushed out at the other, was obviously the answer to this requirement, but the optimum size and spacing for such a parallel array could be determined only by a major recalculation of the theory of graphite lattices.

Rate of Processing How long should each slug be left in the pile? The plutonium concentration would build up fairly rapidly soon after the start (the intermediate steps between absorption of a neutron by U-238 and the final transformation into Pu-239 were known to occur in a short time), and then less rapidly as the U-235 nuclei were used up and the various fission-product nuclei — also increasing in concentration — absorbed a larger and larger fraction of the free neutrons.

The plutonium itself would be subject to fission in the pile, like U-235, and if allowed to build up to a high concentration might be lost by fission at a rate comparable with its rate of production from U-238. On the other hand, the chemical separation of the plutonium from the processed slugs would obviously be simpler for high concentrations than for low. Moreover, it would be desirable to use up a good share of the starting materials, namely, the fissionable U-235 and the convertible U-238, in each slug. These considerations and many others would have to be carefully weighed in deciding on the optimum rate of uranium flow through the factory.

Should it be one big pile or many little piles? A single big pile would be most economical of material and most efficient in terms of plutonium production per kilowatt-hour of fission energy. Small piles, on the other hand, offered several counter-attractions: The first one could be built more quickly than a single large pile, and from it much could be learned to guide in the construction and operation of the later units; moreover, the obvious dangers associated with having all the eggs in one basket would be avoided. By balancing such factors against one another, a certain optimum size of pile, and a corresponding number of piles to give the total production rate required, could be arrived at.

Extraction of Plutonium Extraction of the plutonium from the processed slugs, containing a comparable quantity of some 20 different fission-product elements and many times as much uranium, would be no easy job for the chemical engineers. A process had been developed, involving alternate oxidations and reductions of the plutonium and alternate precipitations and dissolutions, which could be repeated over and over until the plutonium emerged with the required purity, leaving the uranium and the fission products behind. However, the chemistry of this process was based on experiments with only about 0.00002 oz. (20 millionths of an ounce) of plutonium, and there was no assurance that it would work satisfactorily on a scale using pounds of plutonium and fission products and tons of unconverted uranium. It was an open question, for example, how the chemical reactions might be affected by the radiations seething about in the separation tanks.

Fortunately, the air-cooled 1000-kw. pilot plant was in operation, yielding processed slugs at such a rate that the proposed separation methods could be given a pilot-plant trial, before the production piles had begun to function. The method worked! The efficiency of recovery of plutonium in the pilot-plant test was 50% at the very start and was soon pushed up, by a few changes in the process, to between 80 and 90%.

Safety The piles themselves and most of the chemical separation plants would have to be placed within thick shields for protection of personnel against the escaped neutrons and the radiations emitted by the unstable fission-product nuclei. All the business of loading the slugs into the piles and unloading them, of putting the processed slugs into solution and passing the solutions or slurries along from each stage of the separation process to the next, of keeping the piles running at a fixed power level, of monitoring the operation of each stage in the chemical

separation — all these and more would have to be done by remote control from outside the heavy shielding. The highly radioactive fission products left behind in the separation would have to be stored until they had changed into stable atoms that could be safely dumped. Some of the radioactive fission products would be inert gases and these would have to be so widely dispersed in the atmosphere that the radiations from them could not possibly be a menace to persons. Even with these precautions it would still be necessary to keep close watch over the physical condition of every employee and be constantly alert for signs of some unforeseen hazard to health. The biological effects of neutrons and the various radiations were not yet fully understood, and such powerful sources of them as were contemplated were far beyond the range of experience.

There could be no maintenance work done in the piles or in any but the last stages of the separation plant. Every item placed behind the shields — neutron detectors, power level controls, plumbing, pumps, structural elements, and the like — would have to stand up in spite of the flux of neutrons and radiation through it. Once the pile had started, no item could be replaced without shutting down the plant and waiting a long time for the radiations from it to die down to a tolerable level.

There would have to be adequate provision against a runaway reaction within the piles. For one small example, interlocks between the supply of cooling water and the control rods would be necessary, together with a stand-by power source to work the controls if the normal power supply should fail.

These problems are mentioned to suggest how manifold an affair the design of a full-size plutonium factory would be. The magnitude of each problem would be larger, of course, the larger the plant that was planned. As to this, Smyth says (Chapter VII): "The first decision to be made was on the scale of production that should be attempted. For reasons of security the figure decided upon may not be disclosed here. It was very large."

"*The Finished Product Is Being Delivered*"

Nevertheless, the thing was done. An isolated site, convenient to a large supply of pure cold water, was selected in the center of the State of Washington, near the villages of Hanford and Richland on the west side of the Columbia River. Ground was broken for a construction camp in April 1943, and this camp grew to a city of 60,000 people at the peak of construction activity. Five main piles with associated separation plants were originally scheduled. Three have been constructed. The first pile began operating in September 1944. Smyth sums up the story from that point on in the following words:

"In the course of the fall of 1944 and the early months of 1945 the second and third Hanford piles were finished and put into operation, as were the additional chemical separation plants. There were, of course, some difficulties; however, none of the fears expressed as to canning failure, film formation in the water tubes, or radiation effects in the chemical processes, have turned out to be justified. As of early summer 1945 the piles are operating at designed power, producing plutonium, and heating the Columbia River. The chemical plants are separating the plutonium from the uranium and from the fission products with better efficiency than had been anticipated. The finished product is being delivered."

Isotope Separation; The Electromagnetic Method

In the two preceding sections of this account the development of one of the two materials now known to be suitable for a fast-neutron-fission atomic bomb, the new element plutonium, has been traced from the first surmise of its possible existence down to a logical climax, the delivery of the finished product.

Meanwhile the other material now known to be suitable for a fast-neutron-fission atomic bomb, the light-weight isotope of the element uranium, had not been neglected by the investigators. Even before the possibility of making and using plutonium had been clearly grasped, the way to make an atomic bomb with U-235 seemed fairly straight-forward. No nuclear-chemistry factory was needed to supply the material. It existed already in nature. All that was necessary was to strain it out, somehow, from the mixture of isotopes in which it naturally occurs. To separate U-235 from its chemical twin U-238, in sufficient quantity and with sufficient purity for atomic bombs, was the central problem in this phase of the project.

Between 1940 and 1945 every proposed means for separating these two isotopes was studied vigorously. Two different methods were developed to the necessary scale of production. Several others were taken far along toward success and were then abandoned chiefly because of the need for concentrating resources and effort on the two chosen processes. One of these two processes, known as electromagnetic separation, will now be described.

Mass Spectrographs Earlier in this article was given a brief description of how the masses of the different nuclei in a mixture of isotopes are measured. First (to repeat the description) the atoms with neutral electrical charges are changed into positively-charged ions by stripping off one orbital electron from each atom; fast free electrons are used for this job. The ionized atoms are then sent, in a high vacuum, through a combination of electric and magnetic fields so chosen that the path each ion takes is determined by its mass. (The mass of an atom is, practically, the mass of its nucleus, since the orbital electrons weigh so little in comparison.) By measuring the path, which is usually done by locating where it hits a photographic

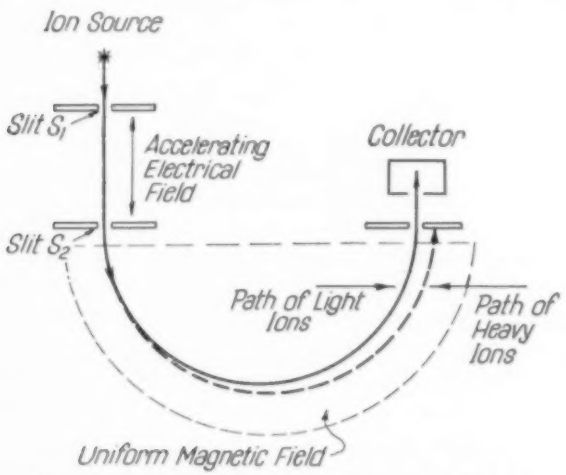


Fig. 8 — Scheme of an Electromagnetic Method for Separating U-235 From U-238. The principles of its operation are described in the text. (Sketch adapted from the Smyth Report)

plate or some other detecting device, the mass can be determined. All such instruments are known as "mass spectrographs".

The possible importance of mass spectrographs for the atomic bomb project is obvious: If ions having different masses take different paths and arrive at different locations, all that is needed to separate the uranium isotopes is to change the uranium atoms into ions, send the ions along their several paths, and have some cans waiting to catch them when they arrive.

This very thing was done in two different laboratories in 1940 for the two important isotopes of uranium. The experiments which proved that the lighter and less abundant nucleus, $_{92}U^{235}$, is the one that is strongly susceptible to neutron fission, were made in that year on microscopic samples separated in mass spectrographs.

Many different combinations of electric and magnetic fields are suitable for the separation, and have actually been employed in mass spectrographs. One arrangement, in use since 1918, is shown schematically in Fig. 8. The electrical field is between the two slits S_1 and S_2. Ions from the source in passing through this field are accelerated and emerge from the slit S_2 with large kinetic energy, practically the same for every ion. For the same kinetic energy, a light ion has less momentum than a heavy ion. Beyond S_2 the ions enter a uniform magnetic field perpendicular to the plane of the paper and move in semi-circular paths with radii proportional to their momenta. The lighter ions move on smaller semi-circles, and can be collected separately from the heavier ions if a receptacle for them is placed as shown.

The Method Looks Unpromising In 1940 it seemed that this method of isotope separation, though useful for experimental purposes, probably could never produce at anywhere near the rate needed for bomb production. In all the long scientific experience with mass spectrographs the ion currents dealt with had always been exceedingly tiny. There were three main difficulties: *(a)* It was hard to produce gaseous ions efficiently and plentifully at the source; *(b)* of the ions produced only a small fraction — those that started out in the direction of the defining slits — could be used; *(c)* the ions in traveling around the semi-circular paths in vacuum would repel one another, and if too many ions were in the space at once this mutual repulsion would distort the semi-circles so much that the streams of light and heavy ions would no longer take distinct paths.

How seriously these factors actually limited the yield can be seen from a numerical example. One of the two mass spectrographs used in 1940 to separate U-235 from U-238 for experimental purposes, if it had been run continuously at its maximum output, would have taken more than four million years to separate the two pounds of U-235 that had been estimated as the minimum requirement for a single U-235 bomb.

In view of these difficulties, which seemed insuperable, the mass-spectrograph or electromagnetic method of separation was set aside and the early efforts were focused on other more promising means of separation, which will be described hereafter in this summary.

The Question Is Re-opened In late 1941, however, the question was re-opened. Larger samples of U-235 were urgently needed for experiments in every phase of the bomb project and the electromagnetic method was still the only means at hand for separating

samples with any high degree of purity. An effort was therefore made to see what could be done about increasing the yield of this equipment.

This effort was surprisingly successful. The very early tests indicated that item *(c)* of the three limitations to large yield — the so-called "space charge difficulty" — could perhaps be largely overcome by making proper use of the ions produced in the residual gas in the magnetic field when it is traversed by the main ion streams. This possibility of separating thick ion streams, if they could be started into the magnetic field, called forth efforts to improve the efficiency of the ion source and the efficiency of utilization of the ions produced in the source. These efforts, too, were successful beyond all expectation.

Within a few months it was evident that the electromagnetic method, far from being useful merely as a tool to provide tiny samples of U-235 for experiments, might be capable of development as a large-scale separator of U-235, in quantities and with purities sufficient for bombs.

The other methods of separation that were then in development were all, as will be seen, multi-stage methods requiring vast plants to be built and vast quantities of unseparated material to be put into process before the first trickle of purified U-235 would appear. Whichever one of them was chosen for final exploitation would have to be carried along through all the stages of design, procurement, testing, and complete construction before it could begin to pay off in the form of U-235 suitable for bombs.

On the other hand, the electromagnetic method could be exploited by small units. The first unit could be put into operation comparatively soon, and experience with it could be used in improving the design and operation of later units. Some freezing of the design would be necessary, of course, but the possibility of change remained if changes appeared to be profitable. Each unit would handle a small batch of material at a time, so that the quantities of uranium then in sight would be enough to start with. It might be that the purity of the U-235 emerging after one separation would not be sufficient for bomb purposes, but the purity could be increased if necessary by running the light-nucleus fraction through the electromagnetic separator a second time. At the worst only a few such separations would be needed, in contrast to the many stages needed in any of the other processes then under development. In short, the electromagnetic method offered many advantages as to adaptability and immediate usefulness. The important thing was to get the yield up by improving the ion source, learning how to use a large fraction of the ions produced, pushing to the limit the strength of the ion beams sent around in the magnetic fields without spoiling the separation, and devising methods of filling up the space in the magnetic field as fully as possible with beams.

Increasing the Yield Work in these directions went on vigorously during 1942, much of it at the University of California, where the discoveries that first opened up the new prospect for electromagnetic separation had been made and where a giant magnet intended for a new cyclotron was available for full-scale experiments.

Smyth reviews the outlook in the fall of 1942 as follows:

"In September 1942, both the gaseous diffusion and the centrifugal methods of uranium isotope separation had been under intensive study — and for a longer period than in the case of the electromagnetic method. Both of these methods — gaseous diffusion and centrifuge — looked feasible for large-scale production of U-235, but both would require hundreds of stages to achieve large-scale separation. Neither had actually produced any appreciable amounts of separated U-235. No large-scale plant for plutonium production was under way, and the self-sustaining chain reaction which was to produce plutonium had not yet been proved attainable. But in the case of the electromagnetic method, after the successful separation of milligram amounts, there was no question as to the scientific feasibility. If one unit could separate 10 mg. a day, 100,000,000 units could separate one ton a day. The questions were of cost and time. Each unit was to be a complicated electromagnetic device requiring high vacuum, high voltages, and intense magnetic fields, and a great deal of research and development work would be required before complete, large-scale units could be constructed. Many skilled operators would probably be needed. Altogether, at that time it looked very expensive, but it also looked certain and relatively quick. Moreover, the smallness of the units had the advantage that development could continue, modifications could be made in the course of construction (or, within limits, after construction) and capacity could always be expanded by building new units."

A Plant Is Built A decision was therefore made to exploit the electromagnetic method on a large scale, continuing meanwhile with the development of the other methods that had been under study for a longer time and that were believed certain to succeed in due

course. Of the several possible designs of electromagnetic separator, the one that looked most promising was chosen for the production plant and all the effort was thrown into improving this design, the others being virtually abandoned.

The separator unit (called a "calutron") as it emerged was not unlike the sketch of Fig. 8, above. The ion source used was a stream of electrons shooting through the vapor of a suitable uranium compound. The ions, after acceleration to high speeds, took semi-circular paths through the magnetic field and were collected in receivers. The chemistry of removing the deposits and extracting the U-235 (always diluted by stray atoms of U-238) was worked out, as were the various problems involved in getting a suitable uranium compound for use in the ion source.

Construction of the first series of electromagnetic units began in March of 1943. The site is in the Tennessee Valley, west of Knoxville, in an area that had already been chosen, because of its isolation and its proximity to a large supply of electric power, for some of the other isotope-separation ventures then under construction. This part of the plant was ready for operation in November 1943. Research on the process continued, and its yield of U-235 was constantly improved in quantity and in purity.

The climax of the matter is stated in the Smyth Report as follows: "The electromagnetic separation plant was in large-scale operation during the winter of 1944-1945, and produced U-235 of sufficient purity for use in atomic bombs."

Isotope Separation; The Gaseous Diffusion Method

Another method of isotope separation that was developed into a large-scale plant is the method of gaseous diffusion. The principles were known in 1940. It had been used, some years before, for separating small quantities of the two isotopes of neon, $_{10}Ne^{20}$ and $_{10}Ne^{22}$.

In the plutonium project every major step, as has been seen, was beset with major uncertainties — first, as to the possible existence of plutonium, then as to its nuclear and chemical properties, next as to the feasibility of getting a chain reaction in natural uranium, and finally as to whether this reaction could be exploited to produce plutonium in interesting quantities. The electromagnetic method, first rejected as a possible means of separating U-235 and later, in consequence of some discoveries not generally foreseen, rescued from the discard and rapidly developed into the first large-scale producer, also had a dramatic career. With the gaseous diffusion method, contrastingly, the whole course of the undertaking could be forecast in some detail even in 1940.

There would be many hard problems, of course, and some of these might turn out to be insoluble. But the general design of a gaseous diffusion separation plant could be sketched in advance, and data were at hand for estimating what size of plant would be needed to yield sufficiently pure U-235 at a rate large enough to be of interest for the bomb project. It was the magnitude of the required plant, rather than the difficult details of its construction and operation, that strained the imagination.

Principles of the Method

To understand why the method would call for a mammoth plant it is necessary to look briefly into the principles of isotope separation by gaseous diffusion.

It will be convenient to talk about some gas that might be used in the actual process — that is, some gaseous compound of uranium. Uranium hexafluoride, UF_6, would be a possibility. Since fluorine, as has been mentioned, has only one isotope $_9F^{19}$, any ordinary sample of uranium hexafluoride gas is composed almost entirely of molecules of only two different masses, depending on whether the uranium atom in the molecule is U-235 or U-238. The light molecules are made up of one atom of U-235 and six fluorine atoms, with a total mass of $235 + (6 \times 19) = 349$ units. The heavy molecules — there are 140 times as many of them — contain U-238 and therefore have a total mass of 352 units each. If these two kinds of molecules can be sorted out from each other the separation of the two uranium isotopes is achieved, for it is an easy matter to extract the $_{92}U^{235}$ from the gaseous compound and reduce it to metallic form, once the $_{92}U^{235}F_6$ has been separated from its chemical twin $_{92}U^{238}F_6$.

The diffusion method utilizes the fact that the two molecules, having different masses, must have different average speeds at the same temperature. The difference in average speed is small, for the difference in mass is small; the light molecules *on the average* move only 0.043% faster than the heavy molecules. Moreover, the speeds of the individual molecules at any one instant vary widely, and the speed of any one molecule varies widely from instant to instant. A census of the molecular speeds at any instant would show that more than 49% of the light molecules are actually going faster than 50% of the heavy molecules! Nevertheless, a small difference in *average* speed is there, and with patience it can be used.

Suppose that some ordinary uranium hexafluoride gas is let loose in one side of an evacuated box divided into two halves by a partition or barrier containing many tiny holes through which the gas can seep slowly. The lighter molecules, because of their higher average speed, will diffuse through the barrier a little more quickly, on the average, than the heavy molecules, and the first gas to arrive on the other side will be slightly enriched in the light molecules; actually, they will be some 0.043% more abundant in this first diffusate than in the original hexafluoride on the other side of the barrier.

As the diffusion proceeds the difference in composition of the gas on the two sides gradually becomes less, and if the diffusion is continued until the pressure on the two sides of the barrier is equalized, the difference in composition disappears altogether. But the first diffusate can be removed before so many of the heavy molecules left on the other side of the barrier have had time to seep through and dilute it down to the normal concentration. This slightly-enriched gas can then be used as the starting material for a second barrier-diffusion separation which will yield a diffusate even richer in light molecules.

By continuing this process through a sufficient number of stages, always promptly removing the first gas to get through each barrier and placing it in the entrance half of the next barrier box, the concentration of light molecules can be gradually built up until finally so few heavy molecules are present that the gas is fit to be processed into U-235 pure enough for atomic bombs. The transfer of the gas from one stage to the next can, of course, be done continuously, with pumps.

Refluxing and Stripping

One important question arises: What shall be done with the gas left behind in each stage? At any stage after the first few stages the gas that is left behind the barrier, though a little poorer in light molecules than the gas that has gone through the barrier and will proceed to the next stage, is considerably richer in light molecules than the gas that started out in the first stage. To throw it away would be over-hasty — somewhere back down the line of stages is a stage that is being fed with a gas which matches this discard gas in concentration, and it is obviously sensible to return this discard to that lower stage and mix it in with the feed gas there. Thus every molecule will have repeated chances at a given barrier, and many of the light ones that do not get through at first will later do so.

Even the discard from the first stage will contain a sizable fraction of the light molecules in the original material, a fraction practically as large as the fraction of the total gas that is left behind in this stage. These light molecules are too precious to throw away, and many of them can be saved by having some stripping stages down below the original feed level, similar to the enriching stages above the feed level.

Optimum conditions for such a cascade process can be worked out theoretically. It turns out to be best to let each stage transmit just half the material that is fed into it, and to return the discard of each stage to the feed of the next-lower stage. The sort of separation plant suggested by these considerations is shown schematically in Fig. 9, with the successive stages indicated by boxes, the barriers by dotted lines, and the pumps, needed for recompressing the gas leaving each side of each stage, by arrows.

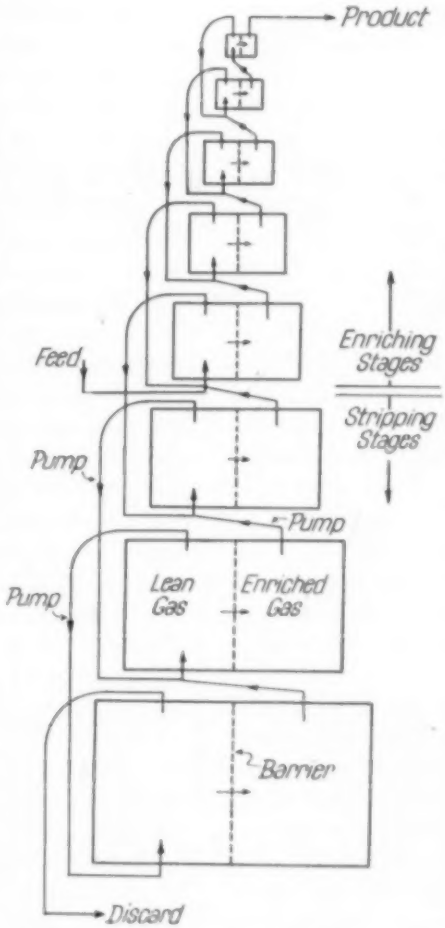


Fig. 9 — Scheme of a Plant for Separating Isotopes by Gaseous Diffusion, as Explained in the Text

A little reflection shows that the quantity of material to be handled in the upper stages is much less than in the lower stages, because only about one molecule in 140 of the original gas is expected to arrive at the top of the cascade. If the same pressure (atmospheric, say) is to be maintained on the entrance side of each barrier, the upper stages can be correspondingly smaller than the lower stages. This fact also is indicated schematically in the figure.

The number of enriching stages necessary to reach the required degree of purity in the final output of $_{92}U^{235}F_6$ can also be worked out, as can the number of stripping stages necessary to wring the original

hexafluoride so dry of bomb material that what is left can economically be discarded. These calculations show that thousands of enriching stages and hundreds of stripping stages are needed. The number of pumps, correspondingly, is many thousands.

The size of the successive stages, to attain a given production rate, can also be calculated. For a plant to supply the needs of the atomic bomb project, many acres of barrier area are required.

These estimates give an idea of the overall size of the undertaking. What about some of the technical problems?

The choice of a process gas is important. Uranium hexafluoride has been mentioned as a possibility and has been used for illustrative purposes in the foregoing discussion. Practically, however, it has several unfavorable features: It is a solid at room temperature and ordinary pressure, it is highly corrosive, and it is not too easy to make and handle. Perhaps some other compound of uranium more suitable for the purposes could be found.

Very extensive work was done to answer this question, always on almost infinitesimal quantities of precious metal.

The entire enormous circulating system would have to be sealed up vacuum-tight to avoid loss of material by outward leaks or contamination with air by inward leaks. Only three holes, for feeding the raw material in and letting out the enriched product and the impoverished waste, were needed or could be tolerated.

The pumps would have to run in vacuum, driven through vacuum-tight seals. They would have to stand any possible corrosive action of the chosen process gas. Pumps of various sizes would be needed, to fit the changing sizes of the successive stages. Power to run thousands of pumps, even after they had been designed and built, would be no inconsiderable item.

The gas in being compressed by the pumps would be heated, and a large cooling system would therefore be necessary to keep the system at optimum temperature.

After the plant had started up it would be necessary to let it run for a time, until the flow conditions in each stage had settled down somewhere near a steady state, before one could begin to draw the light fraction off the top and discard the heavy fraction from the bottom. A considerable quantity of gas would be held in the plant at all times, undergoing separation. The time to get started would be long enough and the quantity of material required to fill the system would be large enough to constitute significant problems.

The *form* of the diffusion stages — whether the barrier should be in tubes or sheets, in large units or small — would have to be decided.

The Barrier Problem The central problem, of course, would have to do with the barrier material. Its holes, it is understood, do not act by being just big enough for the light molecules to squeeze through and not big enough for the heavy molecules (in fact, there is no difference in size between the light and heavy molecules). Rather, the holes are corridors down which the light and heavy molecules diffuse, with the light molecules slightly outrunning the heavy by reason of their slightly greater average speed. The holes need be only so small that the molecules strike the walls much more often than they strike one another. This is, however, a stringent requirement, for the holes need to be about 0.0000004 in. (four ten-millionths of an inch) in diameter or smaller. If the barrier contains many holes much larger than this, the bypass flow through these large openings spoils the separation.

As for the *number* of holes in a given area, it should be large in order to give a high processing rate. The Smyth Report mentions "a barrier made by etching a thin sheet of silver-zinc alloy with hydrochloric acid" as an example of the sort of thing that might be considered.

The holes in the barrier must not enlarge by corrosion and must not plug up. The barrier must withstand a pressure-head of one atmosphere. Many acres of barrier are needed, and the chosen material must therefore lend itself to manufacture on a large scale.

It is a remarkable thing, in view of these difficult specifications, that a number of practicable barriers were actually found. Even while the plant was being built, and after barrier materials were available that would certainly suffice, improved barriers to increase the process rate and the efficiency were still being developed and could be incorporated in the construction.

Successful Operation We pass, as usual, from a review of the salient problems to a simple statement that the thing was done.

The site selected for the gaseous diffusion plant was the region in the Tennessee Valley already mentioned as the site of the electromagnetic separation plant. The original intention, by the way, had been to set up all the production units for the bomb project in this area, but for various reasons the plutonium production piles had been placed instead at Hanford, on the Columbia River.

Smyth says (Chapter X): "Construction of the steam power plant for the diffusion plant began on June 1, 1943. It is one of the largest such plants ever built. Construction of other major buildings and plants started between August 29, 1943 and September 10, 1943.

"Unlike Hanford, the diffusion plant consists of so many more-or-less independent units that it was put into operation section by section, as permitted by progress in constructing and testing. Thus there was no dramatic start-up date nor any untoward incident to mark it. The plant was in successful operation before the summer of 1945.

"For the men working on gaseous diffusion it was a long pull from 1940 to 1945, not lightened by such exciting half-way marks as the first chain-reacting pile at Chicago. Perhaps more than any other group in the project, those who have worked on gaseous diffusion deserve credit for courage and persistence as well as scientific and technical ability. For security reasons, we have not been able to tell how they solved their problems — even in many cases found several solutions, as insurance against failure in the plant. It has been a notable achievement. In these five years there have been periods of discouragement and pessimism. They are largely forgotten now that the plant is not only operating but operating consistently, reliably, and with a performance better than had been anticipated."

Isotope Separation; Thermal Diffusion and Centrifuges

Two other methods of isotope separation that were carried well along the road toward full-scale production of U-235 for bombs will be briefly mentioned. One was the thermal diffusion method; the other was the centrifuge method.

Thermal Diffusion The first application of thermal diffusion to the separation of isotopes was made in 1938, about a year before the discovery of uranium fission. The apparatus was simple, consisting of a hot wire running down the center of a long vertical tube. The operation was easy, for the element to be separated, in gaseous form, was fed in near the middle of the tube and the two isotopes were bled out at the two ends of the tube. On the other hand, the actions that automatically resulted in separation were far from simple, and cannot be explained in any detail here.

Its general principle rests in the fact that, in the temperature gradient between the hot wire and the cool tube, there is a small concentration gradient of the two isotopes, with the light one (let us say) being slightly more abundant in the hot gas near the central wire. Moreover, as the hot gas near the wire moves upward by convection it continually comes alongside a gas in the surrounding downward cool current which is less rich in the heavy isotope than is called for by the temperature gradient, and to which it can lose more of its heavy component. The upward-flowing gas therefore arrives at the top of the tube nearly free of the heavy isotope, and the downward-flowing gas arrives at the bottom nearly free of the light isotope. The countercurrent flow, in this method, serves the same purpose as the refluxing scheme employed in the method of gaseous diffusion.

Discovery and successful use (in Germany, by the way) of this simple means of isotope separation made a considerable sensation at the time, and it was still fresh in the minds of physicists when the problem of separating U-235 from U-238 came to the fore.

Unfortunately, so simple an arrangement would not serve for uranium. Whether it is actually the light or the heavy isotope that prefers the warmer region, and whether the separation effect is or is not large enough to be useful, both depend in a complicated way on the nature of the gas being processed, and no suitable gaseous compound of uranium was found. However, it is possible to use the same principles with a liquid instead of a gas, and the thermal diffusion process that was finally developed employed a certain liquid compound of uranium.

To maintain the temperature gradient between the two sides of the apparatus (the hot wire and the cool tube, in the case described) require an adequate supply of energy in the form of heat. It was primarily this need for power that kept the thermal diffusion method out of the running for a complete separation of U-235.

Centrifuges The centrifuge method is one that at first glance looks most attractive. After all, it is reasonable to ask, if cream is easily separated from milk in a centrifugal separator, why is it not easy to centrifuge the heavy molecules out of some liquid or gaseous uranium compound and drain off the light molecules at the center?

The cases are not entirely the same, however. Cream collects at the top of a bottle in a few hours, but the deuterium-containing heavy water in the bottle does not settle out on the bottom in any length of time. The difference arises from the difference in mass of the two kinds of individual particles.

Each cream globule is so large that the net forces it experiences from the impacts of surrounding molecules, which tend to keep the bits of cream dispersed uniformly throughout the milk, are negligible in comparison with the gravitational differential that tends steadily to float it to the top of the bottle. In contrast, each molecule of heavy water is so small that the dispersing effect of molecular impacts outweighs by far the collecting effect of gravitation.

To get any significant concentration of isotopes in a gravitational or centrifugal field, the field of force must be extremely large. For a centrifuge, this means *extremely* high speeds. At the highest speeds attainable the concentration difference between edge and axis is still small, so that many stages, with a complicated network for transfer and reflux of material, are needed if a fairly pure product is the goal.

In spite of these difficulties, centrifugal separation was for a long time considered seriously as an alternative to gaseous diffusion as the preferred method for separating U-235 from U-238. The scale of the plant would be tremendous — an early estimate called for some 22,000 separately driven centrifuges each 3 ft. long — but the gaseous diffusion method, as we have seen, would be no small venture in itself. Ingenious schemes for increasing the efficiency by using counter-current flow within each centrifuge were devised; the technical problems involved in spinning the centrifuges were attacked and solved. Before this method was finally abandoned in favor of the other, it had been brought to the stage of pilot-plant operation and had given the expected yield and the expected separation.

Fig. 10 — Six-Mile View of Colored Clouds Shooting up From First Atomic Explosion. (U.S. Army photo)

Atomic Bombs

As the various enterprises for producing plutonium and separating U-235 came in sight of success, the final question as to how these materials were to be used in an actual atomic bomb became urgent. In the spring of 1943 a special laboratory, more isolated and even more closely guarded than the other phases of the project, was set up to study the problem of bomb design. Its site was the top of a mesa at Los Alamos, near Santa Fe, New Mexico. The questions facing this laboratory at the start are reviewed in the Smyth Report (Chapter XII) as follows:

"In Chapter II we stated the general conditions required to produce a self-sustaining chain reaction. It was pointed out that there are four processes competing for neutrons:

"1. The capture of neutrons by uranium which results in fission.

"2. Non-fission capture by uranium.

"3. Non-fission capture by impurities.

"4. Escape of neutrons from the system.

"Therefore the condition for obtaining such a chain reaction is that process (1) shall produce as many neutrons as are consumed or lost in all four of the processes. It was pointed out that (2) may be reduced by removal of U-238 or by the use of a lattice and moderator; that (3) may be reduced by achieving a high degree of chemical purity; and that (4) may be reduced (relatively) by increasing the size of the system. In our earlier discussion of chain reactions it was always taken for granted that the chain-reacting system must not blow up. Now we want to consider how to make it blow up.

"By definition, an explosion is a sudden and violent release (in a small region) of a large amount of energy. To produce an efficient explosion in an atomic bomb, the parts of the bomb must not become appreciably separated before a substantial fraction of the available nuclear energy has been released. (For expansion leads to increased escape of neutrons from the system and thus to premature termination of the chain reaction.) Stated differently, the efficiency of the atomic bomb will depend on the ratio of *(a)* the speed with which neutrons generated by the first fissions get into other nuclei and produce further fission, and *(b)* the speed with which the bomb flies apart. Using known principles of energy generation, temperature and pressure rise, and expansion of solids and vapors, it was possible to estimate the order of magnitude of the time interval

between the beginning and end of the nuclear chain reaction. *Almost all the technical difficulties of the project come from the extraordinary brevity of this time interval.*

"In earlier chapters we stated that no self-sustaining chain reaction could be produced in a block of pure uranium metal, no matter how large, because of parasitic capture of the neutrons by U-238. This conclusion has been borne out by various theoretical calculations and also by direct experiment. For purposes of producing a non-explosive pile, the trick of using a lattice and a moderator suffices — by reducing parasitic capture sufficiently. For purposes of producing an explosive unit, however, it turns out that this process is unsatisfactory on two counts. First, the thermal neutrons take so long (so many micro-seconds) to act that only a feeble explosion would result. Second, a pile is ordinarily too big to be transported. It is therefore necessary to cut down parasitic capture by removing the greater part of the U-238 — or to use plutonium.

Critical Size and Reflector

"The calculation of the critical size of a chain-reacting unit is a problem that has already been discussed in connection with piles. Although the calculation is simpler for a homogeneous metal unit than for a lattice, inaccuracies remained in the course of the early work, both because of lack of accurate knowledge of constants and because of mathematical difficulties. For example, the scattering, fission, and absorption of the nuclei all vary with neutron velocity. The details of such variation were not known experimentally and were difficult to take into account in making calculations. By the spring of 1943 several estimates of critical size had been made using various methods of calculation but the limits of error remained large.

"In a uranium-graphite chain-reacting pile the critical size may be considerably reduced by surrounding the pile with a layer of graphite, since such an envelope 'reflects' many neutrons back into the pile. A similar envelope can be used to reduce the critical size of the bomb, but here the envelope has an additional role; its very inertia delays the expansion of the reacting material. For this reason such an envelope is often called a 'tamper'. Use of a tamper clearly makes for a longer lasting, more energetic, and more efficient explosion. The most effective tamper is the one having the highest density; high tensile strength turns out to be unimportant. It is a fortunate coincidence that materials of high density are also excellent as reflectors of neutrons.

"As has already been remarked, the bomb tends to fly to bits as the reaction proceeds and this tends to stop the reaction. To calculate how much the bomb has to expand before the reaction stops is relatively simple. The calculation of how long this expansion takes and how far the reaction goes in that time is much more difficult.

"While the effect of a tamper is to increase the efficiency both by reflecting neutrons and by delaying the expansion of the bomb, the effect on the efficiency is not as great as on the critical mass. The reason for this is that the process of reflection is relatively time-consuming and may not occur extensively before the reaction ends.

Detonation and Assembly

"As stated in Chapter II, it is impossible to prevent a chain reaction from occurring when the size exceeds the critical size, for there are always enough neutrons (from cosmic rays, from spontaneous fission reactions, or from alpha-particle-induced reactions in impurities) to initiate the chain. Thus until detonation is desired, the bomb must consist of a number of separate pieces each one of which is below the critical size (either by reason of small size or unfavorable shape). To produce detonation the parts of the bomb must be brought together rapidly. In the course of this assembly process the chain reaction is likely to start — because of the presence of stray neutrons — *before* the bomb has reached its most compact (most reactive) form. Thereupon the explosion tends to prevent the bomb from reaching that most compact form. Thus it may turn out that the explosion is so inefficient as to be relatively useless. The problem, therefore, is two-fold: *(a)* To reduce the time of assembly to a minimum, and *(b)* to reduce the number of stray (pre-detonation) neutrons to a minimum.

"Some consideration was given to the danger of producing a 'dud' or a detonation so inefficient that even the bomb itself would not be completely destroyed. This would, of course, be an undesirable outcome since it would present the enemy with a supply of highly valuable material.

Effectiveness

"In Chapters II and IV it was pointed out that the amount of energy released was not the sole criterion of the value of a bomb. There was no assurance that one uranium bomb releasing energy equal to the energy released by 20,000 tons of TNT would be as effective in producing military destruction as, say, 10,000 two-ton TNT bombs. In fact, there were good reasons to believe that the destructive effect per calorie released decreases as the total amount of energy released increases.

"On the other hand, in atomic bombs the total amount of energy released per kilogram of fissionable material (i.e., the efficiency of energy release) *increases* with the size of the bomb. Thus the optimum size of the atomic bomb was not easily determined. A tactical aspect that complicates the matter further is the advantage of simultaneous destruction of a large area of enemy territory. In a complete appraisal of the effectiveness of an atomic bomb, attention must also be given to effects on morale.

Methods of Assembly "Since estimates had been made of the speed that would bring together subcritical masses of U-235 rapidly enough to avoid pre-detonation, a good deal of thought had been given to practical methods of doing this.

"The obvious method of very rapidly assembling an atomic bomb was to shoot one part as a projectile in a gun against a second part as a target. The projectile mass, projectile speed, and gun caliber required were not far from the range of standard ordnance practice, but novel problems were introduced by the importance of achieving sudden and perfect contact between projectile and target, by the use of tampers, and by the requirement of portability.

"None of these technical problems had been studied to any appreciable extent prior to the establishment of the Los Alamos laboratory.

"It had also been realized that schemes probably might be devised whereby neutron absorbers could be incorporated in the bomb in such a way that they would be rendered less effective by the initial stages of the chain reaction. Thus the tendency for the bomb to detonate prematurely and inefficiently would be minimized. Such devices for increasing the efficiency of the bomb are called auto-catalytic.

Summary of Status "In April 1943 the available information of interest in connection with the design of atomic bombs was preliminary and inaccurate. Further and extensive theoretical work on critical size, efficiency, effect of tamper, method of detonation, and effectiveness was urgently needed. Measurements of the nuclear constants of U-235, plutonium, and tamper material had to be extended and improved. In the case of U-235 and plutonium, tentative measurements had to be made using only minute quantities until larger quantities became available. Besides these problems in theoretical and experimental physics, there were a host of chemical, metallurgical, and technical problems that had hardly been touched. Examples were the purification and fabrication of U-235 and plutonium, and the fabrication of the tamper. Finally, there were problems of instantaneous assembly of the bomb that were staggering in their complexity."

Atomic Bombs Were Made The deployment of the staff to investigate these problems, and some of the methods that were used to attack them, are described in the Smyth Report. About the details of the solutions finally adopted the Report is, understandably, rather reticent. Here, as in the other phases of the project, we can sum the matter up by saying that the job was done. Atomic bombs were made.

The Weapon and the Future

Concerning the implications of this new weapon, Smyth makes the following remarks in Chapter XIII:

"The end of June 1945 finds us expecting from day to day to hear of the explosion of the first atomic bomb devised by man. All the problems are believed to have been solved at least well enough to make a bomb practicable.....The devastation from a single bomb is expected to be comparable to that of a major air raid by usual methods.

"A weapon has been devised that is potentially destructive beyond the wildest nightmares of the imagination; a weapon so ideally suited to sudden unannounced attack that a country's major cities might be destroyed overnight by an ostensibly friendly power. This weapon has been created not by the devilish inspiration of some warped genius but by the arduous labor of thousands of normal men and women working for the safety of their country.....

"Before the surrender of Germany there was always a chance that German scientists and engineers might be developing atomic bombs which would be sufficiently effective to alter the course of the war. There was therefore no choice but to work on them in this country. Initially many scientists could and did hope that some principle would emerge which would prove that atomic bombs are inherently impossible. This hope has faded gradually.....

"From the military point of view it is reasonably certain that there will be improvements both in the processes of producing fissionable material and in its use. It is conceivable that totally different methods may be discovered for converting matter into energy, since it is to be remembered that the energy released in uranium fission corresponds to the utilization of only about 0.1% of

its mass. Should a scheme be devised for converting to energy even as much as a few per cent of the matter of some common material, civilization would have the means to commit suicide at will.....We find ourselves with an explosive which is far from completely perfected. Yet the future possibilities of such explosives are appalling, and their effects on future wars and international affairs are of fundamental importance. Here is a new tool for mankind, a tool of unimaginable destructive power. Its development raises many questions that must be answered in the near future.

"Because of the restrictions of military security there has been no chance for the Congress or the people to debate such questions. They have been seriously considered by all concerned and vigorously debated among the scientists, and the conclusions reached have been passed along to the highest authorities. These questions are not technical questions; they are political and social questions, and the answers given to them may affect all mankind for generations.

"In thinking about them the men on the project have been thinking as citizens of the United States vitally interested in the welfare of the human race. It has been their duty and that of the responsible high government officials who were informed to look beyond the limits of the present war and its weapons to the ultimate implications of these discoveries. In a free country like ours, such questions should be debated by the people and decisions must be made by the people through their representatives. This is one reason for the release of this report. It is a semi-technical report which it is hoped men of science in this country can use to help their fellow citizens in reaching wise decisions. The people of the country must be informed if they are to discharge their responsibilities wisely."

The Postwar Nucleus

What about those power-marbles that are going to be put in all future automobiles in place of the engines and gas tanks? What about those 15-min. trips from New York to San Francisco in atomic-powered stratosphere rockets? What about that household unit to be built into the basement and thereafter forever do everything from heating the home to making up the beds? What about the deserted coal mines and the stagnant oil fields?

The work described in the Smyth Report, directed as it was toward the single goal of producing a destructive weapon, naturally did not include any exploration of the possibilities of fission and fission power for peacetime uses. Nevertheless, much of the information uncovered in the work is pertinent to non-military uses, and the men engaged in the project could scarcely avoid giving some thought to these possibilities.

Uranium Resources As to the resources, Smyth quotes some early rough estimates (which he allows are probably optimistic) that the nuclear energy available in known deposits of uranium ore is adequate to supply the power needs of this country for 200 years. This figure assumes the U-238 as well as U-235 would be used, the U-238 first being converted into plutonium by capture of neutrons and the plutonium then being fissioned to yield energy.

Critical Size and Enriched Piles The size of any uranium power unit would, of course, have to be at least as great as the critical size for maintaining the chain reaction. As we have seen, when natural uranium is used as a lattice of slugs in a matrix of moderator, the pile is a bulky affair. The critical size is reduced by using heavy water instead of graphite as the moderator, but the weight of a pile employing the natural mixture of uranium isotopes is still to be measured in tons.

One promising possibility, where a smaller unit is necessary, would be to use enriched uranium, enriched either by removing part of the U-238 or by adding plutonium. Not only the bulk of metal, but also the bulk of moderator, would be less for an enriched pile. The atomic bomb itself is, of course, the extreme case of an enriched pile; it needs only a suitable control mechanism to keep the fast-neutron chain reaction ticking along at a constant rate instead of building up explosively. But however small the pile itself, the dangerous neutrons and radiations from it can be contained only by a shield of quite considerable bulk, and this is a troublesome item for any atomic-powered passenger vehicles.

High Temperature Unless some tricky way appears for utilizing the energy more directly, it will have to be taken out of the fission unit in the form of heat and converted into mechanical energy by some kind of heat engine. It is a firmly established principle that the efficiency of a heat engine cannot be high unless the working substance enters the engine at a considerably higher temperature than it leaves. This evidently means that the pile would have to run at a high temperature, and it follows that some substance other than liquid water would have to be used for carrying the heat out

of the pile and into the engine. Liquid bismuth has been suggested as a possible material for this purpose.

Aside from the choice of a suitable coolant, many other difficult problems connected with high-temperature operation of the pile would inevitably arise.

If any such power units are built, the metallurgist concerned with their design will certainly have to give attention, not only to the ordinary properties of the metals he plans to use, but also to two other properties not listed in the handbooks at present. First is the absorbing power of the nuclei for neutrons of various speeds, and second is the ability of the metal to stand up under bombardment of its nuclei by fast neutrons. (The effects of this bombardment are not necessarily negligible; Smyth mentions that the electric resistance, the elasticity, and the heat conductivity of graphite all change with exposure to intense neutron radiation.)

Overlooking the difficulties in the way of getting mechanical power out of the uranium fission reaction, and assuming that it can be done and that mechanical or electrical power will someday be free and plentiful as air is now, there is still the question whether it would make a startling difference to our daily lives. A little reflection suggests — and the conclusion can be sustained by statistical studies — that most of the tangible things we want are not denied us because the electric or steam power to make them is now too expensive. Raw materials, manufacturing plant, and distribution methods would remain costly, even if the power to turn the shafts were entirely free.

Non-Power Uses The chain reaction may be useful in several ways apart from the production of power. The radioactive fission products of uranium, and the radioactive atoms formed by neutron bombardment of other substances placed in a reacting pile, are sure to be useful for many purposes in many fields. Some of them may find application in medicine — just before the war the possibility of treating certain ailments by radioactive materials was being intensively studied. The radioactive materials for all such studies were formerly obtained expensively and in small quantities from such devices as the cyclotron. Now, many of them can be made simply by shoving a sample of material into a reacting pile and letting the free neutrons batter away at its nuclei for a while.

Smyth, summing up the views of the men on the project as to the peacetime future of the uranium chain reaction, writes the following:

"While there was general agreement that a great industry might arise, comparable, perhaps, with the electronics industry, there was disagreement as to how rapidly such an industry would grow; the consensus was that the growth would be slow over a period of many years. At least there is no immediate prospect of running cars with nuclear power or lighting houses with radioactive lamps, although there is a good probability that nuclear power for special purposes could be developed within ten years, and that plentiful supplies of radioactive materials can have a profound effect on scientific research and perhaps on the treatment of certain diseases."

Some Other Possibilities Some of the foregoing discussion applies, of course, only to the uranium chain reaction. This is the only nuclear reaction that has been demonstrated as a practicable source of power within the grasp of man.

On the other hand, there is no certainty that some other chain reaction yielding nuclear energy may not be developed, and no general principle to forbid it. One such reaction, a cycle involving six steps and resulting finally in the transformation of four hydrogen nuclei into one helium nucleus, is now believed to be going on in the sun and to be the source of the sun's energy.

In this sun cycle, as in the uranium fission reaction, the energy liberated represents only an energy of rearrangement of a certain number of protons and neutrons. The mass change per particle corresponding to this energy change is only a minute fraction of the total mass of the particle — less than 0.1% in uranium fission. The most exciting speculation is that it might be possible to destroy massive nuclear particles completely, changing *all* the mass into energy at one sudden blow.

There is no general principle to forbid this. In fact, a converse reaction, the conversion of some of the energy of an X-ray into the mass of two electrons, has been known for years.

Neither of these two possibilities, neither the possibility of getting the nuclei of some common substance to transform themselves in a nuclear chain reaction like that of the sun, nor the possibility of discovering a chain reaction to annihilate neutrons and protons, now seems to be anywhere in sight. The uranium chain reaction is all we have to go on, and even it is apparently far from ready to turn the wheels of the country. However, the lot of the prophet is notoriously hard. Seven years ago no one suspected that a uranium nucleus, lightly touched, could split apart like a ripe watermelon.

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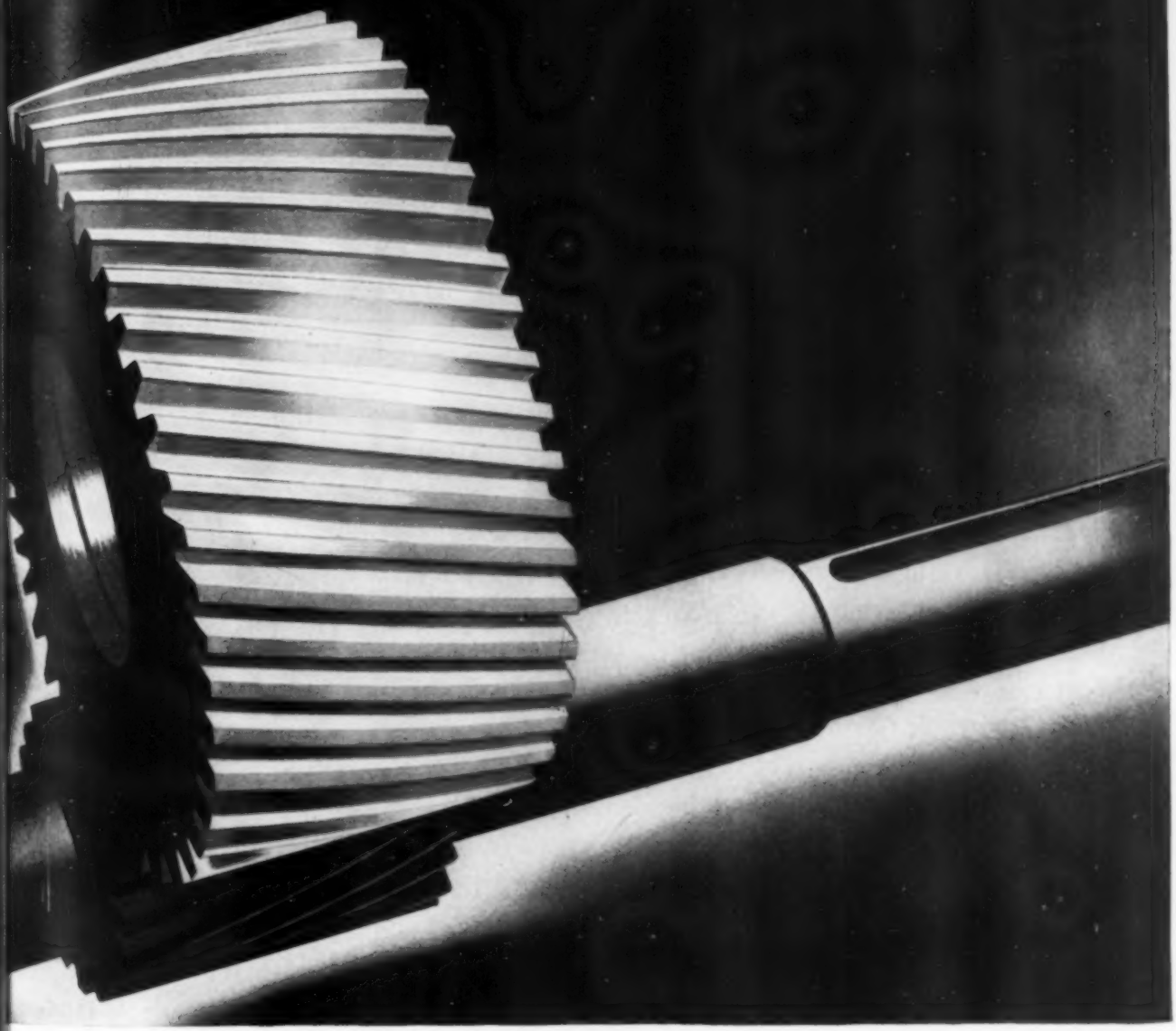

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Personals

GEORGE W. CREMER has returned to the Hardy Co., New York, to do research and consulting in powder metallurgy after two years working at Los Alamos on the atomic bomb project.

THOMAS F. DAVIS, previously with the General Electric Co., has been appointed district manager of the newly opened New York City sales office of the Beryllium Corp. of Pa.

WILLIAM H. SPARROW, formerly metallurgist with the Materials Laboratory of the Sperry Gyroscope Co., is now metallurgical engineer at the East Pittsburgh plant of Westinghouse Electric Corp.

E. A. GLENN, JR., formerly with the American Car and Foundry Co., is now senior metallurgist in the research division of Mack Mfg. Corp., Plainfield, N. J.

RAYMOND F. PARKER, formerly metallurgist at the University of Chicago, is now an engineer at SAM laboratories, Carbide and Carbon Chemicals Corp., New York City.

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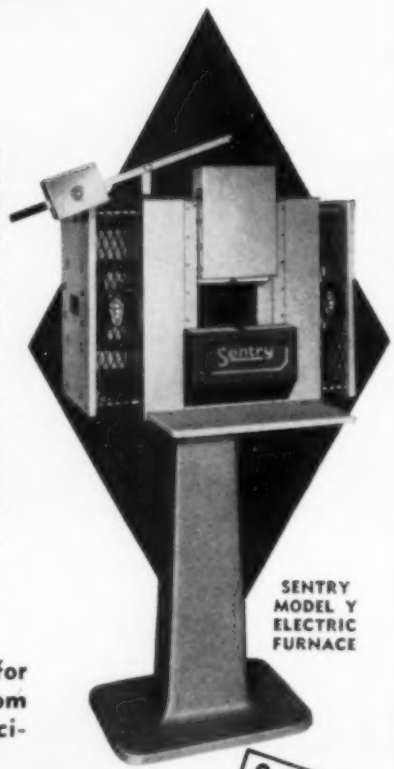

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A Battelle Research Fellowship has been awarded to CLOYD A. SNAVELY, recently released from active duty in the Naval Reserve.

JOHN LOWE III has resigned his position as physicist at Taylor Model Basin to become soils and foundations engineer with the Knappen Engineering Co. of New York, N. Y.

PHILIP EVANS has terminated his connection with the Collins Radio Co., Cedar Rapids, Ia., and is now sales engineer with the Scientific Supplies Co., Seattle, Wash.

HARPER R. WELTON has been transferred from the Atomic Bomb Project, Los Alamos, to the position of scientist at the Rocket Research Laboratory at Inyokern, Calif.

RUSSELL A. BAKER has been transferred from the Davenport, Ia., office of the Minneapolis-Honeywell Regulator Co. to be branch manager of the Syracuse office.

FRANCISCO F. PEREIRA-PINTO having completed his studies at Massachusetts Institute of Technology, has returned to Brazil and is employed at the Rio de Janeiro Navy Yard as assistant engineer.

BERNARD J. HIGGINS, formerly with the Linderme Tube Co., is now general superintendent of the Agaloy Tubing Co., Springfield, Ohio.

L. G. LAWRENCE, formerly with the Aluminum Sheet Rolling Mill, has recently been appointed industrial sales representative of the Reynolds Metals Co. in Philadelphia.

WELD CONLEY is now employed by the Chain Belt Co. of Milwaukee, Wis. He has been at the Naval Ordnance Laboratory during the war.

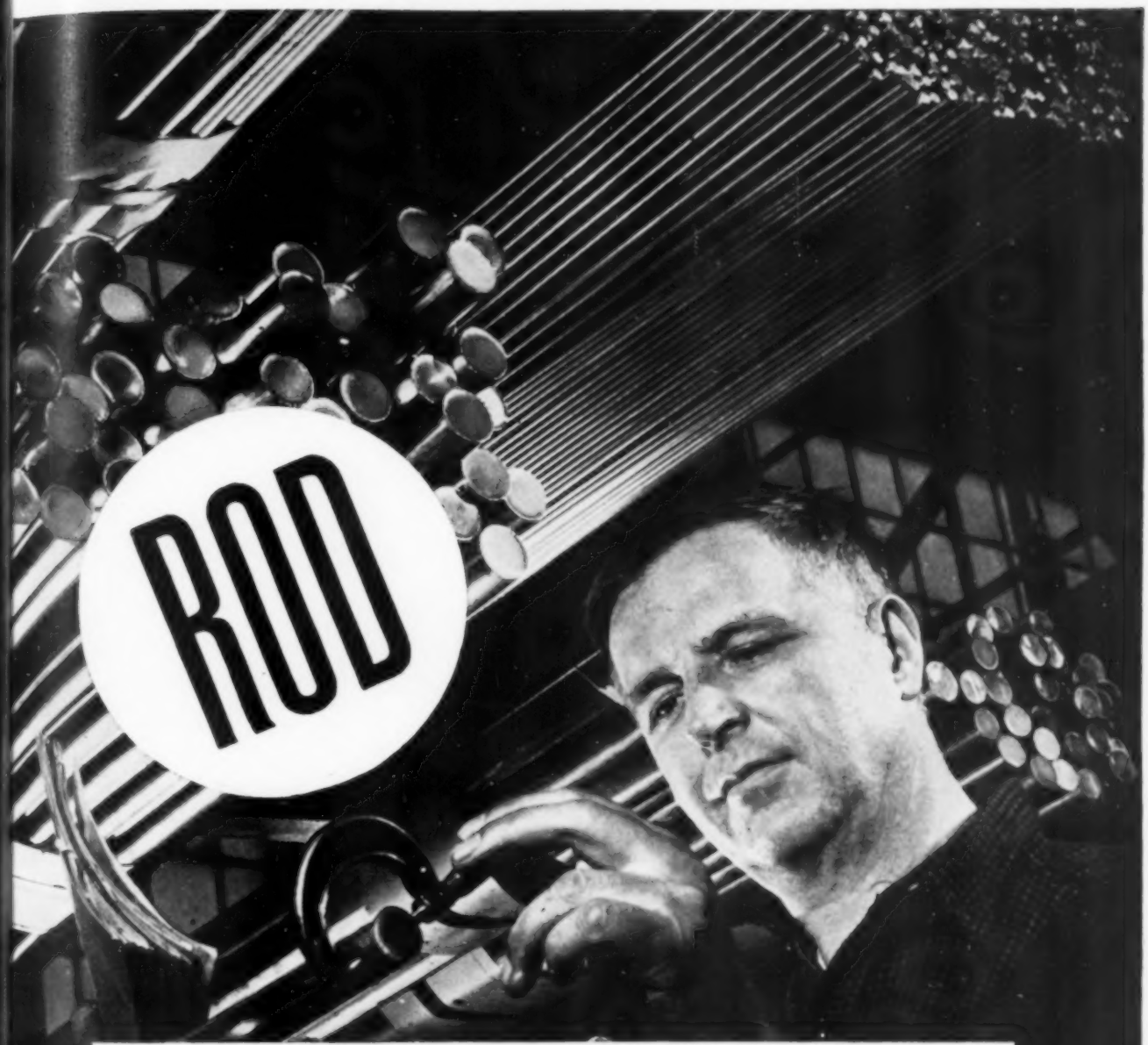
Awarded a Kellex Corp. key for contribution to the U-235 Atomic Bomb: C. F. ROBISON, Harshaw Chemical Co.

ISAAC J. KUNIK has transferred from the Underwood Corp. to the patent law department of P. R. Mallory & Co., Inc., New York.

RALPH W. BAILEY, previously with the United Aircraft Products, is now sales engineer for American Smelting and Refining Co., Barber, N. J.

THOMAS E. MARCH, who has been with A. M. Byers Co., is now assistant superintendent of the machine shop of Rotary Electric Steel Co., Detroit.

RUSSELL HARDY, on release from the Navy, has assumed duties as metallurgist for the Ohio Brass Co., Mansfield, Ohio.



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Commercial Bronze	Special Alloys
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Personals

ROBERT W. KNAPP has been transferred by the Aluminum Co. of America from the Newark, Ohio, plant to the Massena, N. Y., plant where he is assistant department superintendent of remelting.

WILLIAM W. MARTIN, formerly with the Naval Research Laboratory, Washington, D. C., is now superintendent of the electric furnace department with the Pacific States Steel Corp., Niles, Calif.

Triplett and Barton, Inc., have transferred J. J. PIERCE from the Seattle office to the home office at Burbank, Calif., where he assumes the position of assistant production manager.

GEORGE E. PELLISSIER, formerly with Columbia University and the Carbide & Carbon Chemicals Corp., is now with the research and technology department of the Carnegie-Illinois Steel Corp. in Pittsburgh.

WILLIAM L. MOYER, formerly with the Continental Foundry & Machine Co., is now mechanical engineer with the Socony-Vacuum Oil Co., East Chicago, Ind.

H. JEROME SEIM has accepted a position as instructor in chemistry at the Montana School of Mines, Butte, Mont.

KENNETH H. J. CLARKE has returned to the International Nickel Co. of Canada, Ltd. in Toronto, as assistant manager in charge of Canadian sales. He has been special assistant to the Canadian member of the Combined Production and Resources Board in Washington.

R. A. SHATTUCK, formerly with the Crucible Steel Co., is now sales metallurgist with the Edgcomb Steel Co., Philadelphia.

T. L. ROBINSON, previously with the Amplex Division of the Chrysler Corp., is now with the S. K. Wellman Co. of Cleveland.

W. H. MCCORMICK has been recently appointed chief metallurgist of the Pittsburgh Park Works, Crucible Steel Co. of America, following 17 years of service with this company.

WALTER R. BREELER, formerly assistant general manager of the Allegheny Ludlum Steel Corp.'s Dunkirk, N. Y. plant, has been appointed general manager to succeed Charles Spittall, retired.

HARLEY C. LEE, formerly with Basic Magnesium, Inc., has rejoined the Basic Refractories, Inc. in Cleveland, as vice-president.

ERNEST S. KOPECKI has joined the staff of *The Iron Age* as an associate editor following his release from active duty with the U. S. Navy.

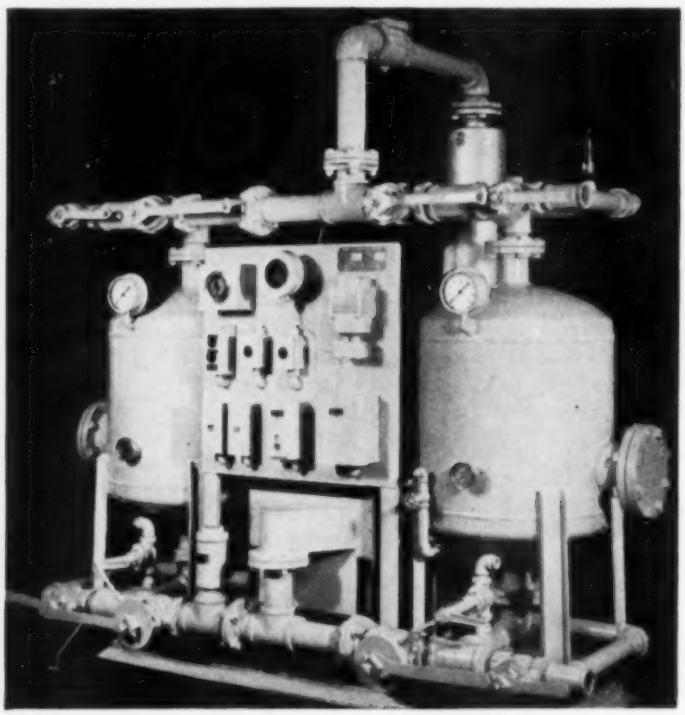
Awarded the "Tribute of Appreciation" of the Gray Iron Founders' Society: DONALD J. REESE of The International Nickel Co., Inc.

MARTIN S. BURG, formerly chief chemist of the Dodge Chicago plant, is now chief chemist and technical foundry adviser of the Certified Core Oil & Mfg. Co., the Socony-Vacuum Oil Co., Chicago.

PAUL SCHMIDT, formerly with the American Non-Gran Bronze Corp., is now with the U. S. Pipe and Foundry Co., at the research department in Burlington, N. J.

MORSE HILL, previously with the Battelle Memorial Inst., is now engaged in research in the metallurgy of powdered metal for the Moraine Products Div., General Motors Corp., Dayton, Ohio.

Honored by the American Welding Society: SAMUEL L. HOYT, technical advisor, Battelle Memorial Inst., asked to deliver the Adams Lecture; H. C. BOARDMAN, research engineer, Chicago Bridge and Iron Co., and DAVID SCHENCK JACOBUS, both awarded honorary memberships.



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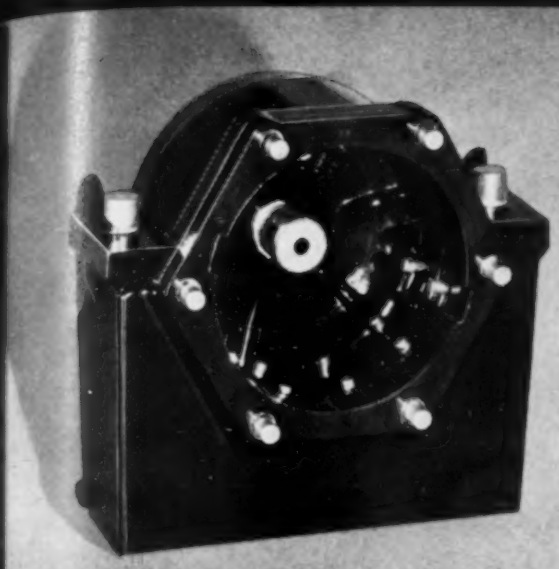


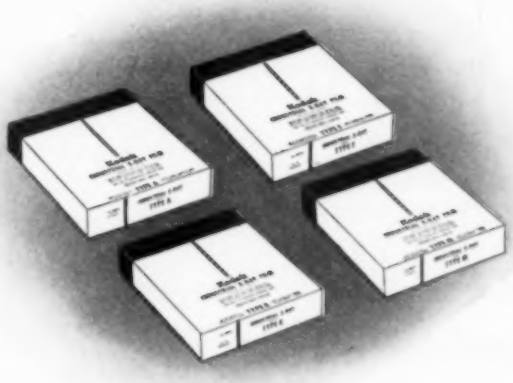
Q. Which x-ray film is first choice for critical examination of plastic parts with metal inserts?

A. Kodak's Type M

BECAUSE it provides the extremely fine grain and high sensitivity necessary for greatest detail in the plastic, as well as the high contrast needed for clearly visualizing the location and condition of the metal inserts, Kodak's Industrial X-ray Film, Type M, is the correct choice. In direct exposures or with lead foil screens, Type M provides maximum radiographic sensitivity.

In addition, the unusually high quality and fine grain of Type M Film meet the increasing emphasis on critical examination of light alloys at average kilovoltages . . . and steel parts at a million volts or more.

Kodak makes the four types of film needed in industrial radiography

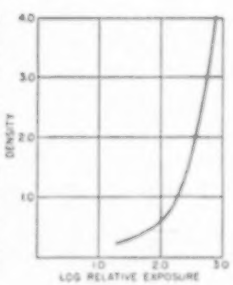


In addition to Type M, Kodak supplies:

Kodak Industrial X-ray Film, Type K . . . for gamma and x-ray radiography of heavy steel parts, or of lighter parts at low x-ray voltages where high film speed is required.

Kodak Industrial X-ray Film, Type A . . . most often used for million-volt radiography of thick steel and heavy alloy parts, and for light alloys at lower voltages.

Kodak Industrial X-ray Film, Type F . . . primarily for radiography, with calcium tungstate screens, of heavy steel parts. The fastest possible radiographic method.



Characteristic Curve, Kodak Industrial X-ray Film, Type M, with direct x-ray exposure or with metallic screens. (Development: 8 minutes at 68° F., in Kodak Rapid X-ray Developer or Kodak Liquid X-ray Developer and Replenisher.)

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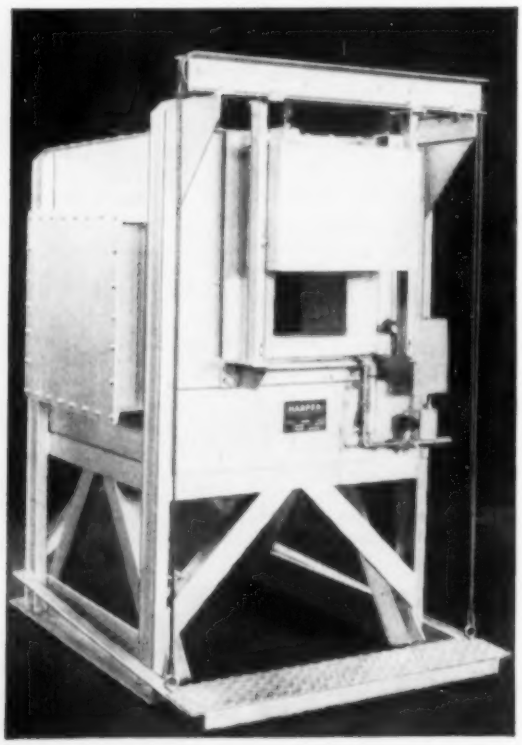

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Harper Custom-Built Furnaces are proving satisfactory under modern exacting heat treating requirements. They provide extreme temperature uniformity throughout the heating chamber plus precision control essential for today's high-grade alloys.

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Personals

H. W. LOWNIE, previously with the Westinghouse Electric Corp., has joined the staff of the Battelle Memorial Inst. as research engineer.

Elected by the American Welding Society: President, W. E. HESS, professor of metallurgical engineering and head of the welding laboratory, Rensselaer Polytechnic Institute; second vice-president, GEORGE N. SIEGER, president and general manager of the S-M-S Corp. The following were also elected directors-at-large: C. M. UNDERWOOD, manager of the weldment department, Northern Ordnance, Inc.; A. B. KINZEL, vice-president of the Electro Metallurgical Co.; and R. D. THOMAS, president, Arcos Corp.

A. T. HAMILL is now associated with the materials engineering dept. of Westinghouse Electric Corp.

JEAN PAUL ELKANN will be director of the Titan Metal Manufacturing Co.'s export office in New York. ARMAND ELKANN has left this country to represent Titan Metal abroad.

JAMES C. PATTON, JR. has been placed in charge of the Heppenstall Co.'s Chicago sales office.

J. O. LOW, JR. has been appointed assistant division manager for Illinois, Indiana and Iowa by the Reynolds Metals Co.

DUNCAN P. FORBES, president, Gunite Foundries Corp., has been made president of the newly formed Z-Metals Research Institute, Inc.

C. S. MERCER has been transferred from the Aluminum Company of America's Spokane plant to the sales division of the company in New Kensington, Pa.

JOHN J. STOBIE, JR. is now with the Apex Smelting and Refining Co. as metallurgist.

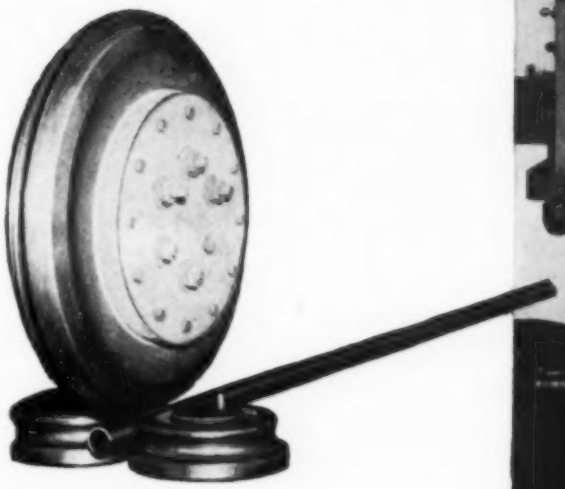
BRUCE G. JOHNSTON has returned to Lehigh University where he is associate director of the Fritz Engineering Laboratory and professor of civil engineering.

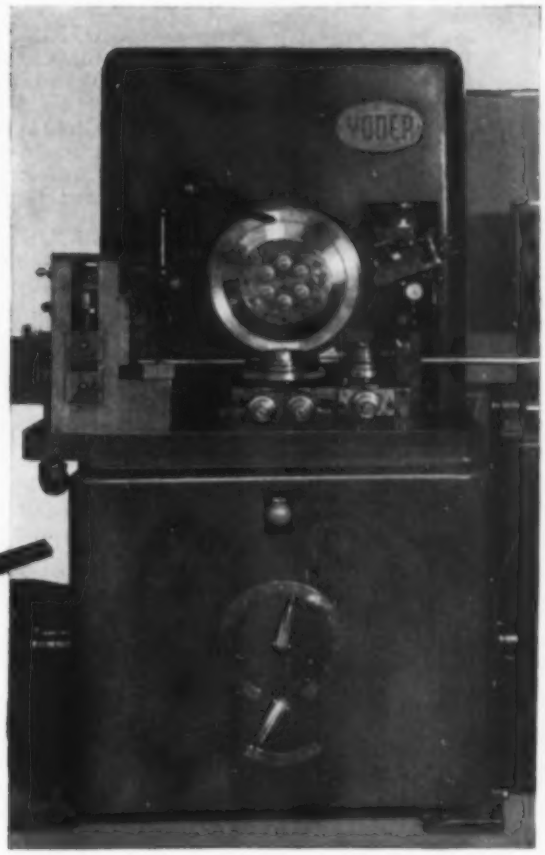
F. D. ARCHER has been appointed midwestern sales manager of The Carpenter Steel Co., Welded Alloy Tube Division, with offices in Chicago.

G. N. EMMANUEL, formerly of the Murray Co., has joined the Babcock & Wilcox Tube Co., New York, as metallurgist.

GEORGE L. ROOT is now with the Reynolds Metals Co., Louisville, Ky., as a development engineer on aluminum textile applications.

MALLORY
Seam Welding Wheels





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STEEL tubing from ¼" to 26" in diameter and from 0.015" to 0.75" in wall thickness is seam welded from steel strip in modern tube mills. In the smaller sizes, production speeds of 100 feet per minute are common.

Coils of steel strip are fed into forming rolls and shaped into tubes. As the two edges meet under pressure, they are butt welded into tubing. What appears to be a single large electrode is actually two wheels separated by insulation. These wheels make contact with each side of the seam and act as current carrying electrodes in performing the welding operation.

Made of Mallory 3* Metal, these two seam welding wheels assure high speed production and a minimum of down time for dressing. Welds are sound, clean and strong.

For resistance welding of various metals—mild and alloy steels, stainless steels, aluminum or plated metals; by spot, seam, flash, butt or projection welding—Mallory engineers have developed electrodes that assure faster, better welding at lower cost. Special Mallory electrode alloys such as Mallory 3 Metal, Elkonite* and Elkaloy A* are helping metal fabricators to set new production records.

Write today for your free copy of the Mallory catalog on resistance welding electrodes. Our engineers will gladly help with any specific problem.

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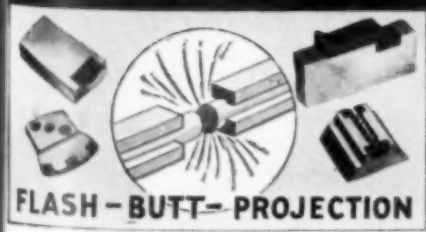
Valuable Information—

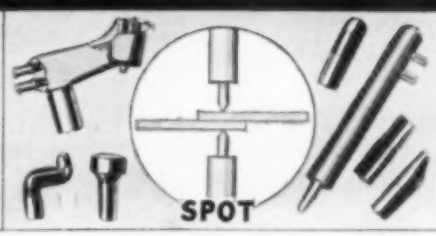
Improved, revised, and expanded, the Mallory Resistance Welding Data Book (3rd Edition) is the most useful manual available on resistance welding methods, machines and materials. Free to those using resistance welding, when requested on company letterhead. Price to students, libraries and educational institutions: $2.50 per copy, postpaid. Board covers, 8½" x 11", 160 pages.

*Reg. U. S. Pat. Off.

P. R. MALLORY & CO. Inc

MALLORY *Standard Resistance Welding Electrodes*





Personals

W. R. Springer is now employed by the Armco International Corp. in the Allied Products Division.

Gus A. Seidel is now employed by Trans-Continental & Western Air Lines, Inc. as senior engineer in the Kansas City maintenance department.

James R. Thain, formerly chief engineer of the Los Angeles Division of the General Metals Corp., has been transferred to the Houston division of the same corporation to assume the position of plant superintendent.

Paul R. Martino has been transferred from the Chicago to the Denver office of the Carnegie-Illinois Steel Corp.

Pvt. W. E. Butler has been assigned to the public relations office of the Clinton Engineer Works, Oak Ridge, Tenn.

George W. Miller is now with the Deep Freeze Corp. where he plans to do research in low temperature treatments.

J. D. Dale is now discharged from the armed services and has resumed his position as vice-president of Charles Hardy, Inc., New York.

William H. Acreman, formerly with Hall Equipment and Products, Ltd., has been made British Columbia manager for Peckover's, Ltd.

Kenneth F. Cropper is now selling mining and metallurgical equipment for the Galigher Co. in Salt Lake City.

Kenneth A. Honroth, formerly with Jack & Heintz, Inc., Cleveland, is associated with the Perfection Products Co. of which he is part owner.

Upon the retirement of James D. Sterling, former manager of the Cleveland office of the Hoskins Manufacturing Co., James W. Sterenberg of the company's Chicago office has been named Cleveland manager and D. E. Swan of the New York office has been transferred to Chicago.

S. K. Oliver, formerly with the General Motors Corp., and Douglas Aircraft Co., is now director of sales and development of the Lithium Corp., Newark, N. J.

Reid B. Gray has been appointed director of the Reynolds Research Institute.

George Goodman has opened an office in Baltimore where he will be distributor for Automatic Temperature Control Co.'s products.

George T. Motock, metallurgical engineer with Metalloy Corporation of Minneapolis, has returned from a three months' stay in Europe where he served as scientific consultant.

H. H. Thomasson has been appointed head of the physical laboratory of the Canadian Westinghouse Co., Ltd.

John H. Schmorde is now an instructor at Warton American Technical School No. 1, in England.

Col. John H. Frye has returned to Columbia Steel & Shafting Co., Pittsburgh, as general manager of sales, after five years leave of absence, during which time he was metallurgical consultant to Gen. G. M. Barnes, chief of ordnance research and development. He was also assistant chief of the materials division of General Barnes' department.

R. I. Hahn has been transferred from the Delco Remy Division to Rochester Products Division of General Motors Corp.

Rex V. Wilson is now associated with the Continental Oil Co., Ponca City Okla., as engineer.

Cecil J. Bier is now partner and chief engineer of the newly formed Biad Powder Metallurgy Co., Pittsburgh.

Henry H. Palmer, formerly of the Corbin Screw Corp., is now product engineer of the mechanical division of General Mills, Inc., Minneapolis.

George A. Grapatin, formerly with the Glenn Tool Co., is now with the White Motor Co., Cleveland.

Roy L. Anderson is now research metallographist, Westinghouse Research Laboratories, East Pittsburgh. He was previously with the Star Brass Mfg. Co.

T. A. Moorman has been appointed manager of Forging & Casting Division of Allegheny Ludlum Steel Corp. in Detroit after serving in a similar capacity in the company's Los Angeles plant.

William C. Heath, chief engineer of the Solar Aircraft Co., San Diego, Cal., has recently returned from a technical survey of German war industry.

Mark H. Kern is now assistant spectrographer with the A. O. Smith Corp., Milwaukee, Wis.

H. A. Raab is now chief engineer with the Edw. S. Christiansen Co., Chicago, Ill.

Charles E. Voigt is now affiliated with the Columbia Steel Co. in Los Angeles.

Gary Steven, formerly with the Curtiss-Wright Corporation, is now with the Frank Morrow Co., Providence, R. I.

Carboloy, Inc. of Detroit has secured the services of Donald L. Schwartz who, until two years ago, was superintendent of the metallurgical laboratory of Cleveland Graphite Bronze Co. In the interim he was with the "metallurgical laboratory" at the University of Chicago, working on the atomic bomb.

. . . for better machining of tough materials—

• Each machining job is different. ThredKut 99 can be used straight or diluted to fit job requirements. Stuart Oil Engineers, "skilled in the art" can adapt this perfectly balanced heavy duty cutting oil to give the results you are looking for. D. A. Stuart Oil Co., Limited, 2743 So. Troy Street, Chicago 23, Illinois.

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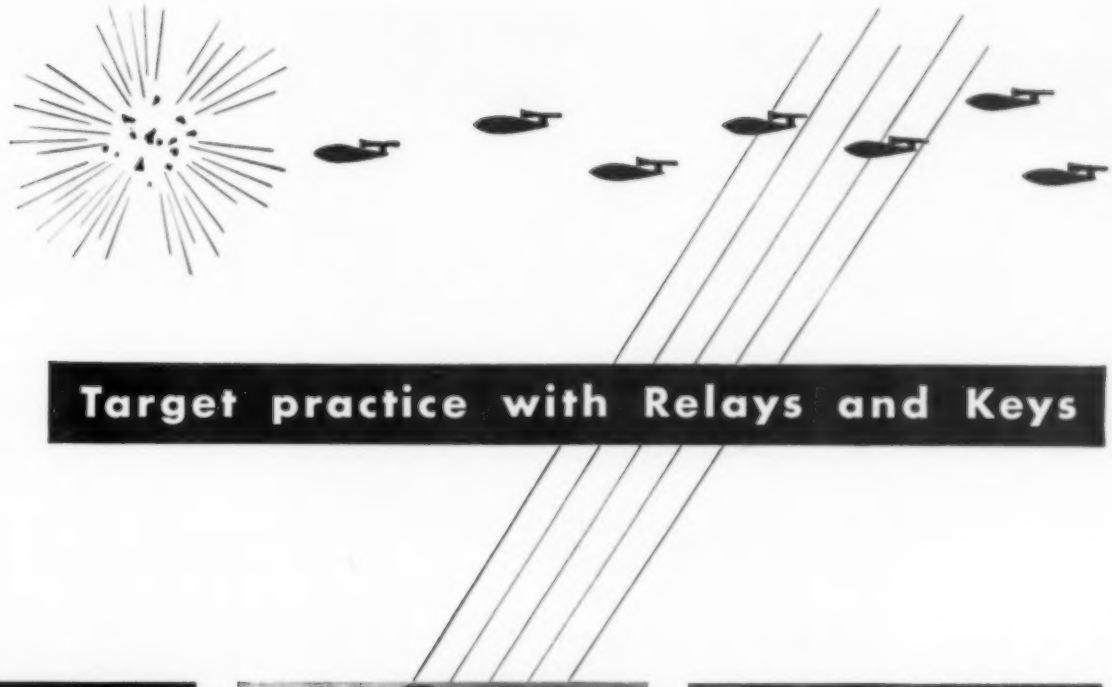
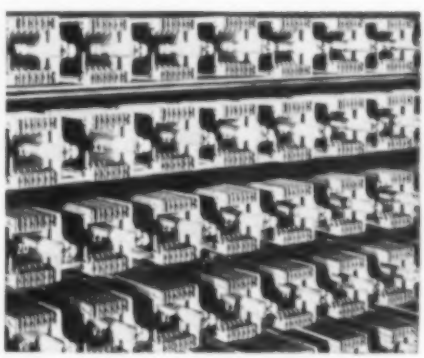
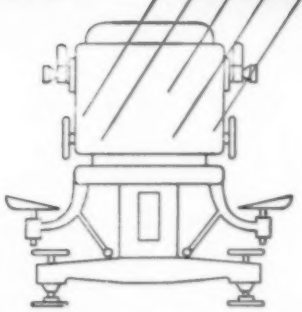


Target practice with Relays and Keys





(Left to right) The operator punches the problem data on tape, which is fed into the computer. The solution emerges in the teletype receiver. Relays which figure out the problem look like your dial telephone system.

In designing the gun-control systems which shot down enemy planes, Army ballistic experts were faced by long hours of mathematical calculations.

So Bell Laboratories developed an electrical relay computer. It solved complicated problems more accurately and swiftly than 40 calculators working in shifts around the clock.

Resembling your dial telephone system, which seeks out and calls a telephone number, this brain-like machine selects and energizes electric circuits to correspond with the numbers fed in. Then it juggles the circuits through scores of combinations corresponding to the successive stages of long calculations. It will even solve triangles and consult mathematical tables. The operator hands it a series of problems with the tips of her fingers – next morning the correct answers are neatly typed. Ballistic experts used this calculator to compute the performance of experimental gun directors and thus to evaluate new designs.

In battle action, Electrical Gun Directors are, of course, instantaneous. Such a director helped to make the port of Antwerp available to our advancing troops by directing the guns which shot down more than 90% of the thousands of buzz bombs.

Every day, your Bell System telephone calls are speeded by calculators which use electric currents to do sums. Even now, lessons learned from the relay computer are being applied to the extension of dialing over toll lines.

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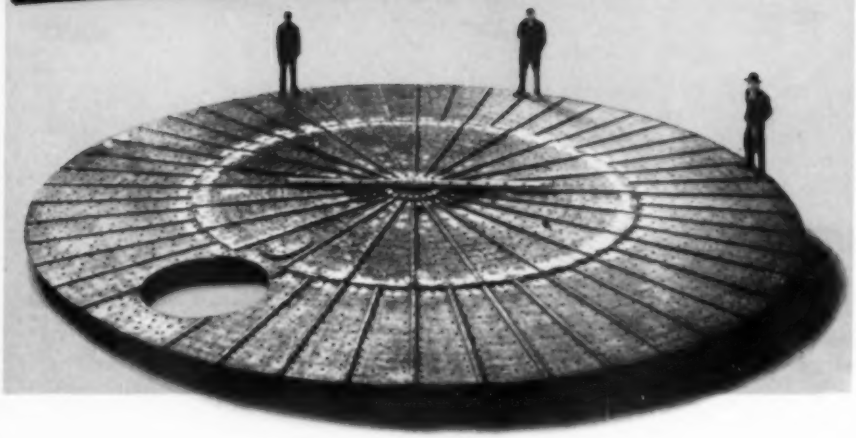

Where Castings Have To Be

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ABSCO-MEEHANITE

Where the job calls for day-after-day, year-after-year service at high temperatures, count on castings of Absco-Meehanite to meet the test of severe and long-continuing use. They are made to specifications that assure resistance to growth, warpage and scaling under heat.

Primarily because of its heat-resistance, Absco-Meehanite was used in the 41-ft. 65-ton reactor plate assembly shown here, and made up of 90 separate castings each fitting into its proper place. Strength and machinability were important contributing factors in determining its acceptance for a special service, the nature of which must remain a military secret.

There are four main classifications and twenty-one different types of Meehanite. In all likelihood, you will find among them a metal with just the right combination of controlled physical properties demanded by your work. Let Absco-Meehanite engineers help you in your casting selection.

ABSCO-MEEHANITE PROPERTIES

1. Strength (Shear, Compressive, Tensile and Transverse)
2. Impact Resistance
3. Corrosion Resistance
4. Wear Resistance
5. Heat Resistance
6. Toughness
7. Rigidity
8. Machinability
9. Pressure Tightness
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Meehanite castings permit close control of physical properties. Write for Bulletin 21 "Meehanite for Heat-Resisting Castings."

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Impact Test for Cast Iron*

APPLICATIONS of modern high duty cast iron often call for a measure of shock resistance and the need has been felt for some time for a simple test to evaluate this quality. It was decided that the Izod type test offers the best possibilities and has the further advantage that suitable machines are widely available. The standard test piece for tough steel, however, is useless for cast iron.

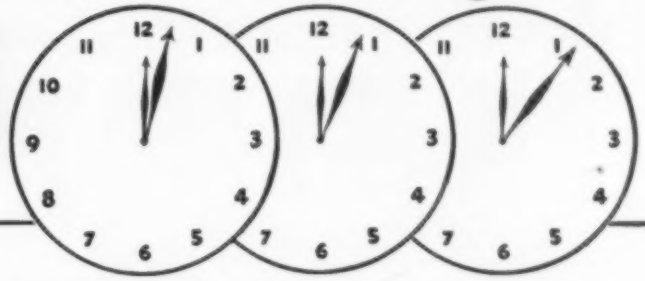
The first series of tests was made on 1.1-in. dia. samples with a 3-in. over-all length and with a groove of 0.05-in. radius located 1⅛ in. from one end. The agreement among seven investigators was much closer for the lower strength material than for high duty cast iron, where the variation could be as much as 50%. It was concluded that these test conditions were not satisfactory. Various alternative forms and sizes of test pieces with both grooves and notches were tried while several were designed with specially shaped heads to avoid the double blow effect whereby the broken part of the specimen shows two or more impressions of the knife edge. While some of the test pieces gave promising results, none proved satisfactorily consistent in eliminating the double blow. This experience confirmed earlier work that a notch was not satisfactory with cast iron.

A second set of tests was made with the B.C.I.R.A. (British Cast Iron Research Association) form (unnotched 0.798 in. dia.) but with the standard 22-mm. striking height rather than the specified 1.3 in. Some measure of consistency was obtained, but the spread of results recorded by each investigator and the over-all spread was felt still to be wider than was acceptable.

Tests showed no evidence that the use of a long bar broken repeatedly is undesirable, while the long bar enables more results to be obtained from a given length than when several 3-in. lengths are used in each test. However, this method would call for some modification of the Izod machine to accommodate the larger specimens. Additional tests showed *(Cont. on page 1356)*

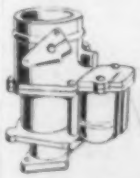
*Abstracted from "The Development of a Single-Blow Impact Test for Cast Iron", by A. B. Everest, J. W. Grant and H. Morrogh, Iron and Steel Institute Advance Copy, June 1945.

How to Cut Metal Cleaning Time to MINUTES



NEW, FAST-ACTION DETERGENT CLEANS FERROUS AND NON-FERROUS METALS...Easy to Handle

TYPICAL USES FOR Solvent "26"



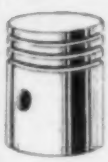
CARBURETORS—Solvent "26" removes gum, gasolene sediment and other accumulations of dirt.

SPARK PLUGS—Solvent "26" safely cleans porcelain; helps loosen carbon deposits.

METAL PLATES AND SCREENS—Solvent "26" restores clear, clean finish to any metal surface.

DIES AND STAMPING—Solvent "26" removes drawing compounds from die-formed or stamped metal.

LABORATORY EQUIPMENT—Solvent "26" frees glass and metal tubing and their supports of gums, varnishes and other incrustations or deposits.



PISTONS—Removes lacquers, gums, resins, etc. from gas, gasolene and diesel engine pistons and rings. Also effective for cleaning all parts of dismantled motors, engines and machinery.

REMOVES:

Oil • Grease • Gums • Varnishes • Lacquers • Paints
Carbonaceous Deposits • Asphaltic Products

FROM:

Steel • Cast Iron • Aluminum • Porcelain • China
Chrome and Nickel Plate • Stone • Precious Metals
Brass • Washable Fabrics

Used throughout the war in critical industry as a superior cleaning agent, newly-developed SOLVENT "26" is now available for all industrial needs.

Offering many advantages in time, labor and cost over other present cleaning methods . . . Solvent "26" is so effective a detergent it can be used at *ordinary* room temperatures.

The fast action of Solvent "26" reduces cleaning time from hours to minutes on dismantled engine parts and all kinds of machinery. Simply dip, rub, brush or spray it on. Then flush clean with hot water.

Mail the coupon today for literature and information leading to a demonstration of this unique product in your own plant.

CITIES SERVICE OIL COMPANY
ARKANSAS FUEL OIL COMPANY

CITIES SERVICE OILS
ONCE-ALWAYS

Cities Service Oil Company
Room 536
70 Pine Street
New York 5, N. Y.

Gentlemen: I am interested in a demonstration of Solvent "26"—at no cost or obligation.

Name.....

Title.....

Company.....

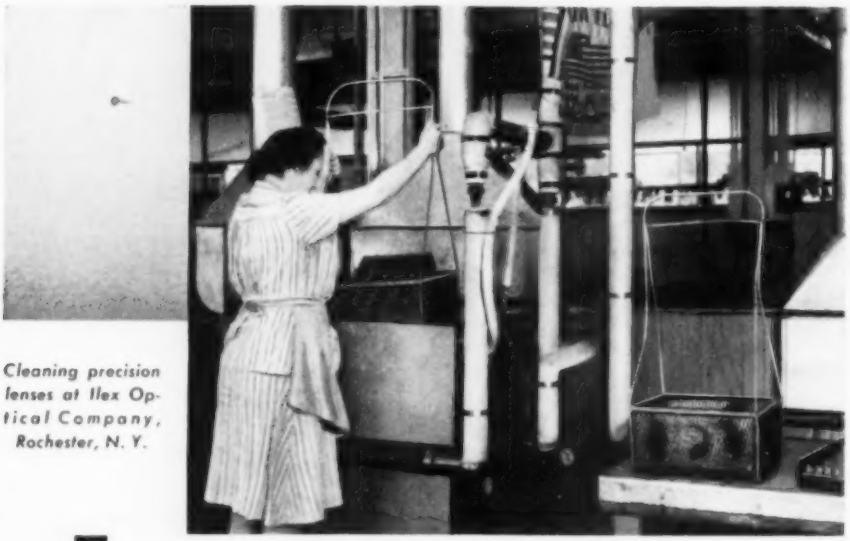
Address.....

City.....State.....

PERM-A-CLOR

IS USED FOR

THE TOUGHEST VAPOR DEGREASING JOBS



Cleaning precision lenses at Ilex Optical Company, Rochester, N. Y.

THE removal of blocking pitch from precision lenses is one of the toughest applications for solvent vapor degreasing. Practically every known hazard that would contribute toward solvent breakdown is present.

For many years PERM-A-CLOR has been used not only for high-speed production cleaning of precision lenses, prisms and many other parts in the optical industry, but in every industry where critical operating conditions exist. In every application where aluminum is processed, or high humidity is prevalent, or where mixed-metal runs are being cleaned, it is economical to specify PERM-A-CLOR—the solvent with the utmost stability.

★

For your most critical applications, specify PERM-A-CLOR.

For applications requiring average stability—TRIAD

DETREX SOLVENTS ARE STOCKED AT:

Akron, Ohio	Fort Wayne, Ind.	Portland, Ore.
Baltimore, Md.	Grand Rapids, Mich.	Providence, R. I.
Birmingham, Ala.	Houston, Texas	Reading, Pa.
Brooklyn, N. Y.	Indianapolis, Ind.	Rochester, N. Y.
Buffalo, N. Y.	Kansas City, Mo.	St. Louis, Mo.
Cambridge, Mass.	Lima, Ohio	Salt Lake City, Utah
Charlotte, N. C.	Los Angeles, Cal.	Saginaw, Mich.
Chattanooga, Tenn.	Lockland, Ohio	San Francisco, Cal.
Chicago, Ill.	Milwaukee, Wis.	Seattle, Wash.
Charlestown, Mass.	Minneapolis, Minn.	Somerville, Mass.
Cincinnati, Ohio	Nashville, Tenn.	South Bend, Ind.
Cleveland, Ohio	New Haven, Conn.	Springfield, Mass.
Dallas, Texas	Newark, N. J.	Syracuse, N. Y.
Dayton, Ohio	Niagara Falls, N. Y.	Tulsa, Okla.
Denver, Colo.	Oakland, Cal.	Toledo, Ohio
Detroit, Mich.	Philadelphia, Pa.	Waterbury, Conn.
El Monte, Cal.	Pittsburgh, Pa.	Worcester, Mass.

DETREX Corporation

13006 HILLVIEW AVE.

DETROIT 27 • MICHIGAN

Solvent Degreasers - Metal Parts Washers - Processing Equipment - Industrial Cleaning Compounds

Cast Iron

(Cont. from p. 1354) that any variations caused by prior transverse testing were well within the limits of variation in the test and any possible influence of the direction of prior bending could not be found.

The double blow effect was studied in more detail since it was suspected of introducing a serious source of error. It has been recorded on all types and sizes of test pieces. The double blow is actually caused by the knife blade itself. It was not eliminated by modifications of the vise, grips or tup arrangements nor by reduced energy of blow. Study of numerous broken samples and high speed photography records have shown that the secondary blow is apparently formed by the test piece hitting the underside of the knife edge with considerable force after the fracture is complete. A comparison of actual test results indicates that the presence of the double blow does not affect the impact value.

Although tests made on bars deliberately within the range 0.794 to 0.802 in. showed the average impact value was reasonably consistent, it is felt that the machining tolerance should not be greater than ±0.001 in. on the diameter.

An independent series of tests by the B.C.I.R.A. confirmed the general trend of the former results in that the most promising specimens were the 1.1-in. grooved bar and the 0.798-in. plain bar with a 22-mm. striking height. Therefore, a third series of cooperative tests was made with these two types. The results obtained by some investigators were still very erratic but there was a greater tendency toward uniformity than had been obtained previously. There was no explanation for the divergent results obtained by some investigators and the results still showed too wide a dispersion to justify the immediate standardization.

However, a recommended procedure has been evolved. It provides for a 0.798-in. dia. by 3-in. long specimen to be broken in a standard 120-ft-lb. Izod machine with a striking height of 22 mm. using special grips. The Izod machine should be in good condition and rigidly fixed. Test pieces may be machined from the 1.2-in. dia. by 21-in. long transverse test bar or from the broken halves of this bar, after testing. Wherever possible at least three tests should be made and averaged.

CONSULT WITH COLGATE ON

LIGHT METALS

If you are interested in substituting light metals for present materials—have a tricky or complicated job, where Aluminum, Magnesium or Stainless Steel might be used....that is our specialty!

Colgate Aircraft Corporation, as a result of its wartime experience in building sub-assembly parts for planes, has brought something new to the light metal field.

Of course we will take parts fabrication and assembly jobs where the blueprints are all ready for production.

But one of our biggest assets is the ability to lick the hard problems, to relieve the manufacturer of the need for planning and engineering his products in light metal production.

IMPORTANT DISCOVERY

Colgate, long ago, discovered that the most important aid to a manufacturer often was *before* the job went into production.

We found out that the most helpful aid was the furnishing of a complete *engineered service* that took the problem at its inception and worked it out almost from the "idea basis" to completion.

This *realistic* co-operation in the planning, followed by quality control, constant supervision, and experienced personnel operating the latest in modern facilities, is one of the reasons why Colgate is earning a good reputation for assisting manufacturers in fabricating aluminum, magnesium or stainless steel parts and assemblies.

Deliveries on time is another factor in Colgate operations which is a part of the *dependability* of its *engineered service* available to the industry.

WHY NOT FIND OUT?

Before dismissing the possibility of the use of light metals as a substitution for present products, why not write to us about your problems?

Our *engineered service* is available to you for consultation without charge and a conference may result in furnishing you with important aids to your business.

COLGATE *Aircraft Corporation*

AMITYVILLE, LONG ISLAND . . . NEW YORK

LIGHT METAL PRODUCTS DIVISION

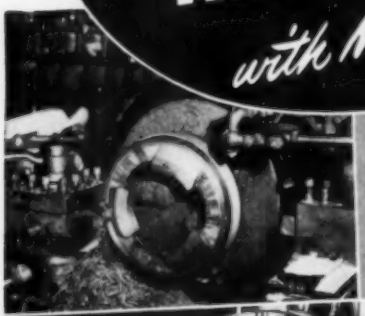
Scores of Tough Jobs Prove

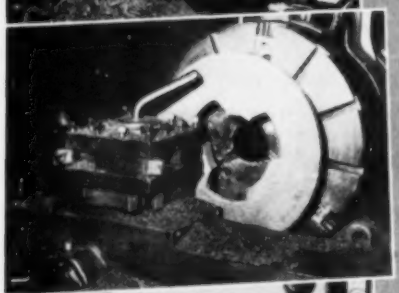
KENNAMETAL

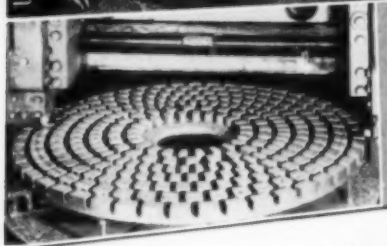
K6

Machines CAST IRON

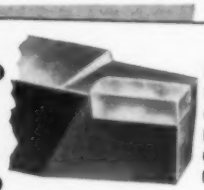
with Maximum Economy





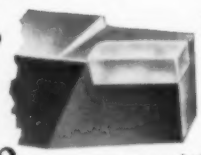


Kennametal Grade K6 is one of the most useful and needed recent developments in tool materials for machining cast iron and non-ferrous metals. It is an improved tungsten carbide having unusual strength in combination with exceptional abrasion-resistance and high hardness. The four performance studies outlined below are typical of scores of comparative service results that clearly show the superior properties of K6 for interrupted and continuous cutting on cast iron.



REMOVES TONS OF METAL FROM CHILLED CAST IRON PARTS, AT TOOL COST OF 74 CENTS PER TON

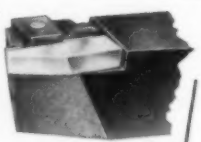
Style 12 Tool with K6 tip turns 1½ lineal miles between grinds! Other makes of carbide failed at all speeds and feeds. After 10 regrinds K6 tip is used on lighter jobs. Operation—turning cast iron piston trunks, 21½" diameter, having six 3" or 4" ports (interrupted cut). Chilled around port holes. Very sandy surface. Feed—.0937S". Depth of cut—½". SFM-120.



TURNS OUT 10 TIMES AS MANY PIECES, ON ROUGH CASTING, BETWEEN REGRINDS

One to four pieces between grinds was the best performance recorded by other carbides on machining a webbed flange of inferior grade cast iron, having hard spots, and sand pockets. K6 turns out more than 40! Operation—turning outside diameter and facing both sides of hub and rim. Feed—.032". Depth of cut 1/16" to 3/8". SFM-280.

MULTIPLIES OUTPUT, ON FACING OPERATION, ON SANDY IRON CASTING



Replacing another make of carbide with a Style 11HD Tool having a clamped-on, advanceable K6 tip, made possible tripling the feed, doubling the cutting speed, and facing 8 times as many pieces per regrind. Operation—facing sandy iron castings. Feed—.036". Depth of cut—1/8" to 3/16". SFM-150 at start, 320 after tool entered cut.

The best way to prove that K6 makes possible better, faster machining on cast iron, at lower tool costs, is to try it in your own shop—then compare tool performance and overall costs. Order a few Kennametal blanks, or complete tools, now—and ask our district field engineer, who is fully acquainted with the properties of K6, to help you get maximum results from this new and improved tungsten carbide—Kennametal Grade K6.

CUTS 35 PIECES (on Abrasive Electric Iron) AS AGAINST 3 FOR CARBIDE PREVIOUSLY USED

This unique tool, tipped with Kennametal K6, turns out 11½ times as much work between grinds as the carbide tool previously used. Operation—finish trepanning cut on electric iron part. Feed—.003". SFM-210. Accurate tolerances and good finish required, and produced.

KENNAMETAL

SUPERIOR CEMENTED CARBIDES

KENNAMETAL Inc., LATROBE, PA.

High Speed Drilling*

A NEW drilling system recently developed at Detroit Reamer and Tool Co. portends speeds in mass production drilling far beyond present practices. With ordinary unannealed cast iron, the recommended speed of 900 r.p.m. for a conventional $\frac{13}{32}$-in. drill and a feed of 0.007 in. would give a rate of about 6.3 in. per min. With the hyper drilling system, an $\frac{13}{32}$-in. drill running at 1800 r.p.m. drills 6¼-in. thick cast iron at about 20 in. per min. and better. One reason for the high speed is that the drill goes through without stopping to clear the chips as is ordinarily done in deep hole drilling.

In the standard drills, the size of the drilled oil holes and their coolant capacity are limited by the amount of solid metal between grooves. As an improvement, a drill was developed with a milled oil channel which is then sealed with a silver soldered strip of mild steel. Thus the area of the duct is considerably increased without in any way impairing the cutting edges.

The hyper drills are made of high speed steel heat treated to standard specifications. They are of the milled duct type but with the channels open. They look like conventional four-flute drills with two intermediate flutes serving as coolant ducts. The drills are longer than ordinary as they are driven from the flutes. The bushing is a specially designed rotary type, running in precision ball bearings in a stationary housing. This bushing acts as a seal for the coolant and as a seal between itself and the workpiece. The lower end of the inner shell is cut away to form two sharp cutting edges which serve as chip breakers. The conical section of the bushing is cut away for chip disposal. The intermediate flutes are closed by rubber seals so the coolant is forced downward along the intermediate flutes to the point of the drill. Coming through under a high pressure, the coolant then forces the chips upward through the major flutes.

Although the method is somewhat more involved than the conventional methods of drilling, it is designed for mass production rather than for short runs. Once set up, it shows remarkable results.

*Abstracted from "Speed and Precision With Hyper Drilling", by Karl Stad, *The Tool Engineer*, July 1945, p. 33.

THEY GAVE THEIR PROBLEM THE HOT SEAT

5400 per hour WITH TOCCO

TO improve engine performance and cut costs, this manufacturer altered the design of his tappet. A steel push rod seat, brazed to the tappet cylinder, was the basic idea. The problem was to harden the seat without scale, without distortion of the cylinder and without affecting the braze . . . and to do this *at low cost*.

A TOCCO Induction Heating machine with special fixture solved the problem with these results:

TOCCO electrical induction heats the seat only to a uniform depth. TOCCO's integral quench then cools the area, hardening it to 60 R.C. This quick, localized treatment avoids scaling and distortion, and does not disturb the nearby braze. The quality of the result is attested by millions of these tappets now in service.

And as for *low cost:* Two wheel fixtures keep the tappets turning into the inductor and quench. Operators simply load the wheels. The tappets drop out at the bottom at a *cost-cutting rate of 5400 per hour*.

How about *your* problem? The TOCCO Engineer nearby and the TOCCO Development Laboratory are at your service. Write for free copy of "Results with TOCCO".

THE OHIO CRANKSHAFT COMPANY • Cleveland 1, Ohio

TOCCO

INDUCTION
HARDENING, BRAZING
ANNEALING, HEATING

For making better tap holes, and for quick hot repairs at critical points inside the furnace, more and more operators are using 695 Plastic. Where conditions are severe and operating temperatures unusually high, this basic plastic refractory gives excellent service.

IT'S A GOOD PHONE NUMBER TO KNOW

THERE are times when a steel man has his refractory troubles—he may be making tap holes too often, having excess bottom delay time, having too many break-outs, or an old bottom may need a major repair or renewal.

Then is the time to think of the "Basic" Engineer. Just give him a call, and he will be right over. For he's your "First Helper" in any emergency on refractories—he is trained to work that way.

The "Basic" Sales Engineer is different from many of the sales representatives who ask you for business—different in that he is charged specifically with a double responsibility. His first duty is to help his customers to more effective use of refractories, and thus to contribute to increased steel production and lower refractory costs. He works on the theory that if "Basic" products acquit themselves satisfactorily, the orders will be forthcoming, too.

You can always depend on the advice of the "Basic" Engineer, for he is a practical steel man, too. In addition to his sound knowledge of basic refractories, he knows steel production as a man with actual experience in making open hearth and electric furnace steel.

So write his phone number at the top of your list. Comes any emergency, it's a good number to know.

BASIC REFRACTORIES, INCORPORATED 845 HANNA BUILDING *Cleveland 15, Ohio*

Three 600-lb pins for a "Nordberg" Diesel engine, on the way to be loaded into Homocarb furnace in foreground. Pins will be carburized to a uniform depth of .090", slowly cooled, reheated in the Homocarb furnace and quenched. Nordberg Mfg. Co., Milwaukee, uses two Homocarb Method equipments for this and similar work.

CARBURIZING'S War Record Points to Peacetime Savings

As a cost-cutter and a production-increaser, the process of carburizing comes out of the war ready to help solve many problems in the design and manufacture of steel parts which require hard surfaces.

Carburizing was, of course, ready for widespread quality use in the late 1930's, but its quality possibilities were not particularly well known. Enormous use in war work was the fact which proved on a wholesale scale that quality and quantity can go hand in hand in carburizing.

A large percentage of all this high-grade, low-cost carburizing was and is done by the Homo Method of carburizing. For Homocarb gives full, easy and automatic control of the "furnace" factors in the process. There are four of these factors—Temperature, Time, Quality and Quantity of carburizing medium and Control of cooling speed under protective atmosphere. They are fully explained in our Catalog T-623, sent on request. If however you have a carburizing problem actively in work, we suggest you see an L&N engineer. And if you already have a Homocarb Furnace, ask about the new quick-cooling feature which can be added.

Mass-production carburizing of airplane engine parts, in big batteries of Homocarb Furnaces, shows suitability of Homocarb Method for high-quality high-production work. Photo courtesy Perkins Machine & Gear Co., Springfield, Mass.

LEEDS & NORTHRUP COMPANY, 4927 STENTON AVE., PHILA. 44, PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

Ad T-623(20)

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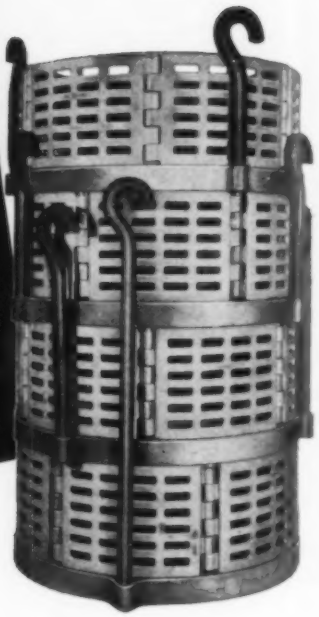
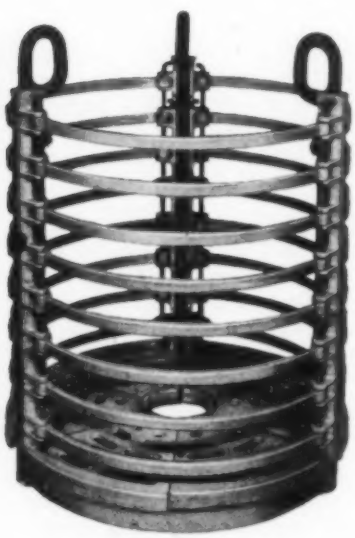
What do YOU Need in a Carburizing Fixture?



1 LONG LIFE

All these fixtures are made of our Alloy-502, with 35% Nickel and 18½% Chromium—a composition of extreme durability.



2 EASE OF LOADING

The fixtures are sectionalized in such a way as to make loading easy, and also to prevent undesired mixing of parts.

3 FREEDOM FROM TROUBLESOME WELDS

There are almost no welds in these carburizing containers. Strains are thus avoided, and greater durability results.

All these pit-type carburizing fixtures are of light weight, in relation to their strength, and the work-loads that they handle. They are well liked because of their simplicity and their long life on the job. Often they are individually designed to meet certain requirements. If you do pit-type carburizing you would be helped by detailed information on these fixtures. Write us. Hoskins Manufacturing Company, Detroit 8, Michigan.

4 SIMPLICITY IN PARTS REPLACEMENT

The absence of welds makes the structural units easy to renew. This is a matter of convenience, and economy.

HOSKINS PRODUCTS

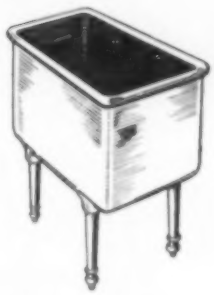
ELECTRIC HEAT TREATING FURNACES • • HEATING ELEMENT ALLOYS • • THERMOCOUPLE AND LEAD WIRE • • PYROMETERS • • WELDING WIRE • • HEAT RESISTANT CASTINGS • • ENAMELING FIXTURES • • SPARK PLUG ELECTRODE WIRE • • SPECIAL ALLOYS OF NICKEL • • PROTECTION TUBES

HEATING ELEMENT WIRE — Chromel — NICKEL-CHROMIUM

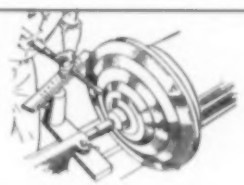
Want a Tip?

on selecting your most practical Stainless Sheet finish

WHITE, PICKLED—No. 1 —for deep draws. Tanks, bins for chemicals—the dough trough shown at the right —heavy duty industrial equipment—applications in which stainless works with its sleeves rolled up.



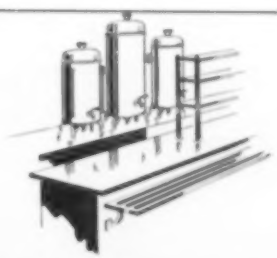
DULL, SMOOTH—No. 2D —for forming, drawing, dishing —*and spinning*. Mild cold finishing has rendered the surface smooth and dense. Tools ride easily over the surface. Stainless shapes itself to your product—and your needs.



BRIGHT, DIFFUSELY REFLECTIVE—No. 2B —for formed products where "look" is a factor. Painstakingly rolled and inspected for perfect uniformity of surface, 2B calls attention to itself. And where special sheens and lusters are required, 2B can be brushed or polished after fabrication.

POLISHED, SATIN, REFLECTIVE—No. 4 —one of the most dramatic of stainless finishes—and the easiest to keep clean. The finish for food service equipment, decorative trim, dairy equipment — wherever it pays to boast, "This is stainless."

JML Co B-M1



EASTERN STAINLESS
STEEL CORPORATION
BALTIMORE 3, MARYLAND • Distributors' stock available in most areas
CHICAGO • CLEVELAND • DALLAS • DETROIT • LOS ANGELES • NEWARK • PHILADELPHIA

Now ZIRCONIUM*

by the Hydride Process . . .

COMMERCIALLY AVAILABLE IN SEVERAL FORMS

Metal Hydrides Incorporated now offers industry Zirconium in powder, ingot and hydride forms, and in alloys with copper, nickel and cobalt in either powder or ingot form.

Zirconium Hydride (ZrH_2) is a 300 mesh powder containing in combined state about 1.5% to 2% of hydrogen. This hydrogen can be safely and simply evolved from the powdered metal if it is heated above 300°C.

Zirconium metal powder is also a 300 mesh product and is practically free from occluded gases. It is so reactive that it can be stored or shipped only in moist condition and must be dried carefully in small lots, preferably in special vacuum tanks.

The powdered alloys of Zirconium-Copper (35% Zr), Zirconium-Nickel (35% Zr or 50% Zr) and Zirconium-Cobalt (50% Zr) are 200-300 mesh products which are not mechanical mixtures but are true alloys in the form of a powder in which every particle is a true alloy-particle. Thus, the sintering of these powdered alloys is a simple operation, involving no danger of oxidation, and the time of diffusion is cut to a minimum.

Ingots of both pure Zirconium and of the above mentioned Zirconium alloys also are commercially available.

* One of Zirconium's most interesting properties is its resistance to all acids except hydrofluoric and "Aqua Regia". Another extremely interesting property is its alloying characteristics with other metals. In the case of copper, it forms an age-hardening alloy (1% of Zirconium providing a strength of about 70,000 pounds per square inch) without appreciable lowering of the heat and electrical conductivity of the copper, indicating possible uses in heat radiators, electric switches, etc. Zirconium-Copper alloys also can be used as an addition to the ladle for the final deoxidation of special bronzes. Zirconium-Nickel and Zirconium-Colbalt alloys are of particular interest as magnetic materials. Pure Zirconium metal, in the state of gas-free, extremely reactive fine powder, is used as an addition to flash lights, as a "getter" in vacuum tubes, etc. Following is a brief summary of the physical properties of the three basic forms of Zirconium now available from Metal Hydrides Incorporated:

PROPERTY	ZIRCONIUM	ZIRCONIUM HYDRIDE
Color		
Amorphous form	Black Powder	Black Powder
Crystalline or fused form	Hard bright silver	Does not exist
Specific Gravity	6.4	.....
Melting Point	1900°C.	Decomposes above 350°C.

Send for this 20 page booklet. Describes the Hydride Process, its purpose and field of application; Properties of Metallic Hydrides; Titanium; Zirconium; Titanium-Copper Alloys; Zirconium-Copper Alloys; Powdered Alloys, Etc. Write today to Dept. C.

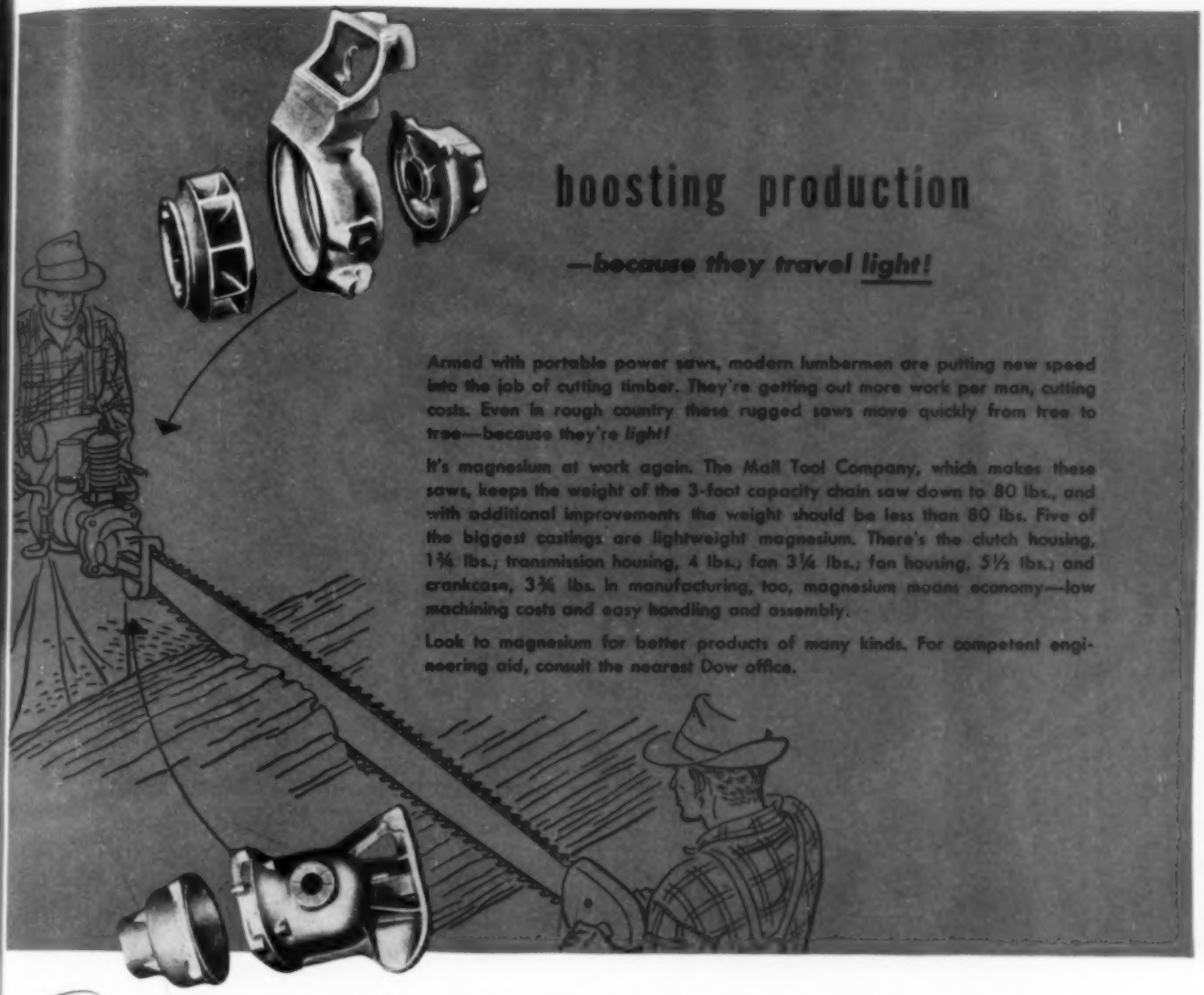
METAL HYDRIDES INCORPORATED

HYDRIMET PRODUCTS • TITANIUM HYDRIDE • TITANIUM POWDER • TITANIUM INGOTS • ZIRCONIUM HYDRIDE • ZIRCONIUM POWDER • ZIRCONIUM INGOTS • METAL NITRIDES • COPPER-TITANIUM • COPPER-ZIRCONIUM • BERYLLIUM-NICKEL • TITANIUM-NICKEL • COBALT ALLOYS • *CALCIUM HYDRIDE

*A foolproof, convenient, easily transported source of pure hydrogen.

Helping Industry to Put the Right Metal in the Right Place

16 Congress Street, Beverly, Massachusetts



boosting production

—because they travel light!

Armed with portable power saws, modern lumbermen are putting new speed into the job of cutting timber. They're getting out more work per man, cutting costs. Even in rough country these rugged saws move quickly from tree to tree—because they're *light!*

It's magnesium at work again. The Mall Tool Company, which makes these saws, keeps the weight of the 3-foot capacity chain saw down to 80 lbs., and with additional improvements the weight should be less than 80 lbs. Five of the biggest castings are lightweight magnesium. There's the clutch housing, 1¾ lbs.; transmission housing, 4 lbs.; fan 3¼ lbs.; fan housing, 5½ lbs.; and crankcase, 3¾ lbs. In manufacturing, too, magnesium means economy—low machining costs and easy handling and assembly.

Look to magnesium for better products of many kinds. For competent engineering aid, consult the nearest Dow office.

Ready... to make products move!

MAGNESIUM

LIGHTEST OF ALL STRUCTURAL METALS

A plentiful supply of magnesium is now readily available from Dow, the pioneer producer and leading fabricator for nearly 30 years.

Backed by continuous Dow research, standard fabrication methods and shop techniques are used by modern plants in all parts of the country.

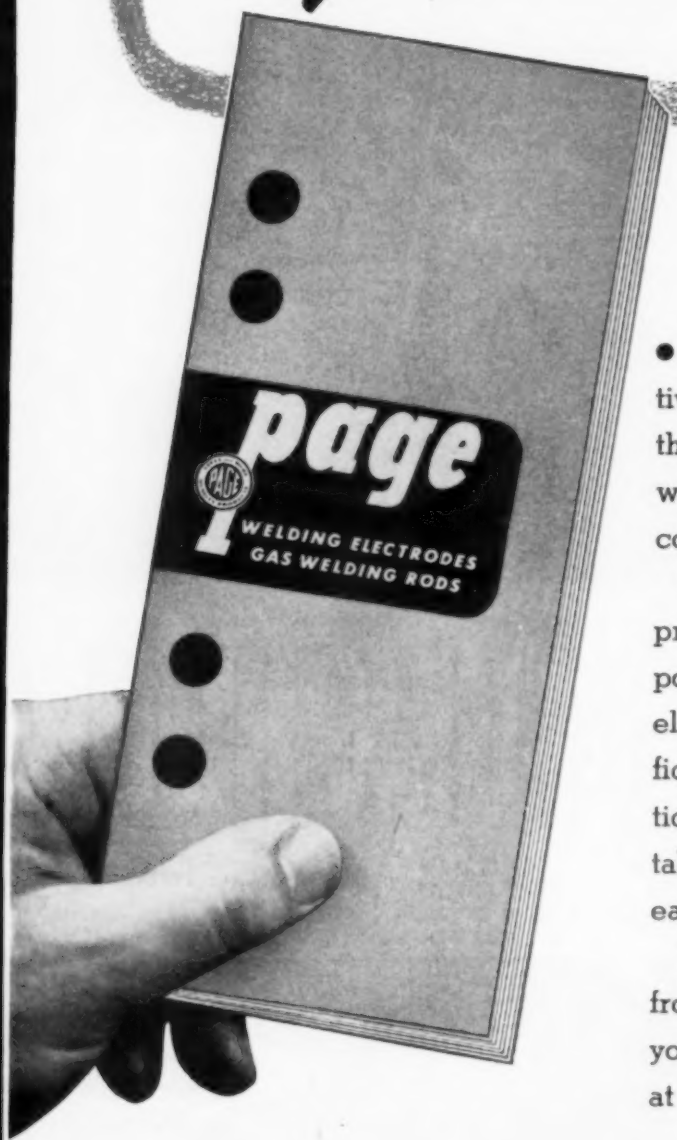
This magnesium griddle is one of the many consumer items and industrial products now being manufactured of magnesium alloys.

MAGNESIUM DIVISION • THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN

New York • Boston • Philadelphia • Washington • Cleveland • Detroit • Chicago • St. Louis • Houston • San Francisco • Los Angeles • Seattle

PAGE *Welding* ELECTRODES

IT WILL SOON BE *Dog-Eared* FROM USE



● This new **PAGE** book is so informative, so complete and so easy to use, that we prophesy in many shops it will soon become dog-eared from constant use.

Twenty-eight different classes of production welding are listed. Opposite each is the recommended electrode or gas rod. Complete specifications and welding characteristics of each electrode and rod are tabulated for quick reference and easy reading.

You can get copies of this book from your **PAGE** distributor. Or, if you prefer, write to the **PAGE** factory at Monessen, Pa. Ask for DH-821.

ACCO

Monessen, Pa., Atlanta, Chicago, Denver, Los Angeles, New York, Pittsburgh, Portland, San Francisco, Bridgeport, Conn.

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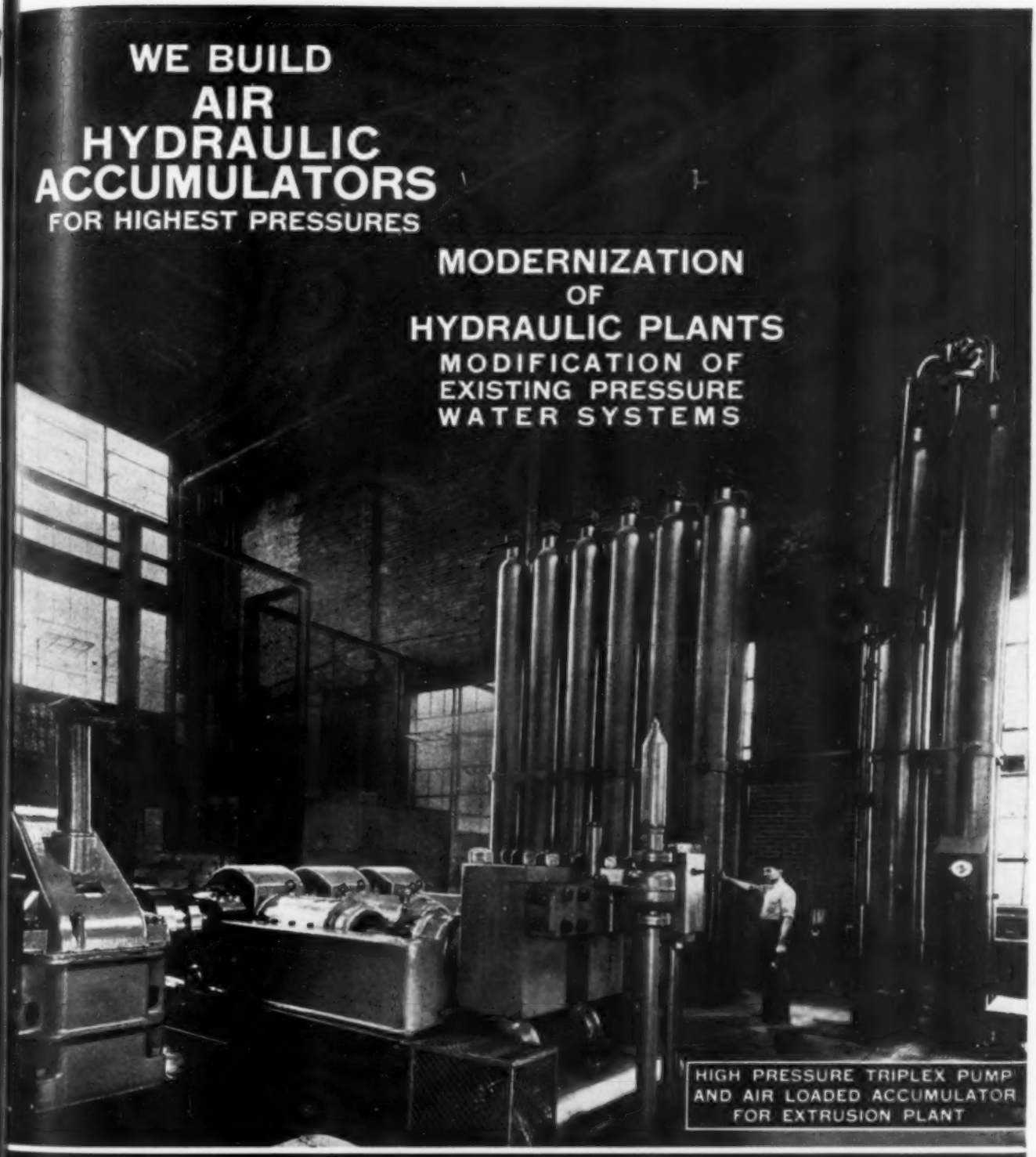
AMERICAN CHAIN & CABLE



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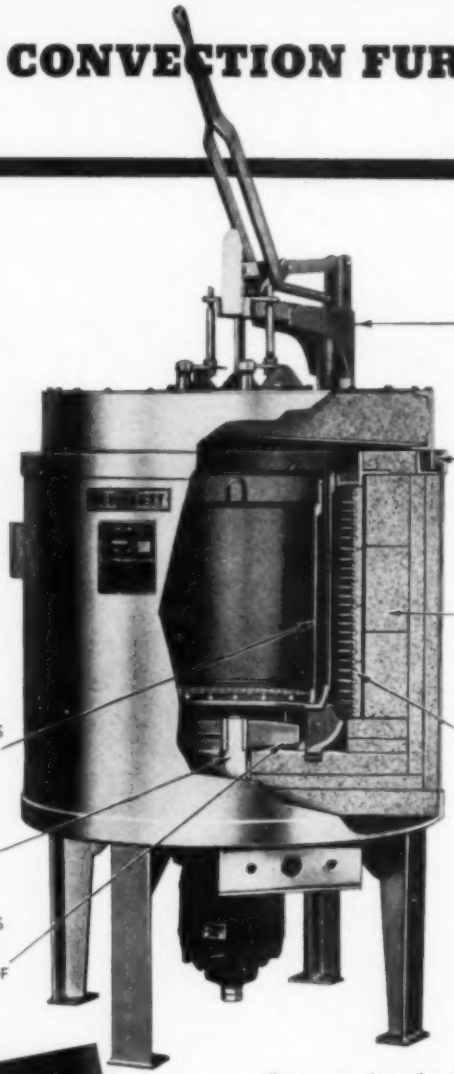
HEVI DUTY *Pit Type* CONVECTION FURNACES

The Hevi Duty Pit Type Convection Furnace is used for aluminum heat treating, and for drawing and annealing ferrous and nonferrous metals up to 1400° F.(760° C.). The use of a high velocity fan assures uniform heating of the work even when the parts are small. This furnace can be built for use with protective atmospheres at temperatures up to 1750° F. (955° C.).


SIMPLE MANUAL COVER OPERATING MECHANISM
COVER SEAL
PREFORMED GRADED INSULATION
HEVI DUTY HEATING ELEMENTS SYMMETRICALLY ABOUT THE HEATING CHAMBER SUPPLY HEAT LOSSES WHERE THEY OCCUR
BASKET SIDE PROVIDES DEAD AIR SPACE TO PREVENT DIRECT HEATING
FAN AND SHAFT REMOVABLE THRU THE HEATING CHAMBER
LARGE FAN PROVIDES HIGH RATE OF CIRCULATION WITH UNIFORM HEATING OF WHOLE CHARGE

Cut-away view of an HD-1620 Pit Type Convection Furnace.

Two large Hevi Duty Pit Type Convection Furnaces in an alloy steel fabricating plant.

Send for Bulletin HD-1041

HEVI DUTY ELECTRIC COMPANY

HEAT TREATING FURNACES HEVI DUTY ELECTRIC EXCLUSIVELY

MILWAUKEE, WISCONSIN

Prevent Failure

OF CRITICAL PARTS

with Surface-Hardened STAINLESS

No chances can be taken that critical parts will fail in life-saving equipment like this aircraft crash truck. When in operation the nozzle must move freely and easily so that the operator can "sweep" the flaming gasoline away from the trapped flyers with the high-pressure water stream.

Even under the terrific force developed by the high-velocity jet, the bearings in the swivel joints of the nozzle must not bind or seize. And of course there must be no rust or corrosion to impede the smooth action of these bearings.

That is why Samuel Eastman Company installs bearings of Surface-Hardened Stainless Steel in the swivel joints of the nozzle.

With the new Surface-Hardening Process (Malcomizing), it is now possible to take advantage of the inherent strength and corrosion-resistance of stainless steel, and at the same time to get wear-resistant surfaces as hard as 95 Rockwell 15N (73 Rc).

Wherever remarkable ability to stand up under abrasive wear, combined with resistance to heat, corrosion, and oxidation will prevent failure of critical parts, you should consider the Stainless Surface-Hardening Process.

For More Information

If you want to know more about the advantages of this new process and how you can use it, write for the technical bulletin. If you wish, one of our metallurgical engineers will discuss it with you.

JLMCo CS-L1

STAINLESS SURFACE HARDENING CO.

255 BENT STREET • CAMBRIDGE 41 • MASSACHUSETTS

SUBSIDIARY OF INDUSTRIAL STEELS, INC.

America's Largest Warehouse for Stainless Sheets, Bars, Tubings, Wire, Valves, Fittings, Electrodes and Hardware

LIGHTER . STRONGER . FASTER

Framed in Yoloy, the Steel of Tomorrow

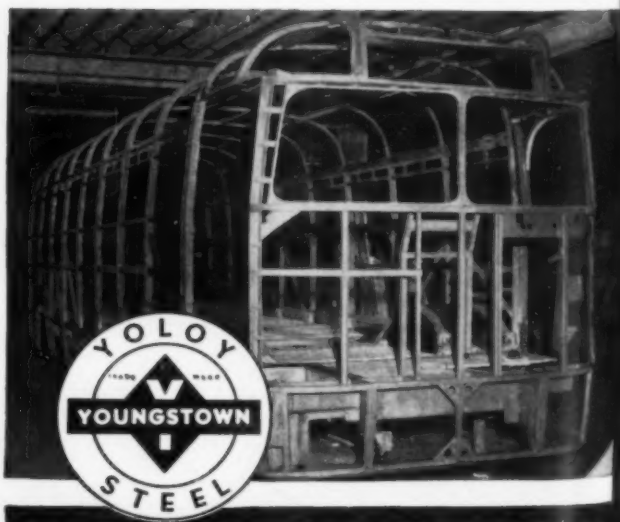
A new era in fast, safe, efficient coach transportation begins with a Yoloy-frame, as illustrated in this 33-passenger MAINLINER, now being built by C. D. Beck & Company, Sidney, Ohio for fast inter-city service.

This entirely new design permits faster acceleration and braking with no sacrifice in safety, because the Yoloy frame reduces weight and increases strength at the same time.

In trucks, trailers, coaches, railroad cars... wherever light weight must be coupled with strength, Yoloy is being picked for special new jobs in transportation.

Yoloy is a low-carbon, nickel-copper alloy steel. It is easily welded, drawn or machined, has exceptional corrosion resistance, high tensile strength and great impact strength. It increases payloads, steps up performance, cuts dead weight.

You too, can go places with Yoloy. Write for further informatiom.



YOUNGSTOWN

THE YOUNGSTOWN SHEET AND TUBE COMPANY

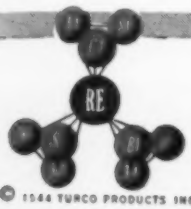
YOUNGSTOWN, OHIO

Manufacturers of

CARBON · ALLOY AND YOLOY STEELS

Electrolytic Tin Plate-Coke Tin Plate-Pipe and Tubular Products-Sheets-Plates-Conduit-Bars-Rods-Wire-Nails-Tie Plates and Spikes-Alloy and Yoloy Steels.

Surface Chemistry*–new science of dirt removal–now insures higher standards of metal cleaning and preparation



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*THIS IS TURCO *SURFACE CHEMISTRY*

Surface Chemistry is the scientific balance and application of these cleaning factors to a specific problem.

WA–Wetting Action
EA–Emulsifying Action
SV–Saponifying Value
SA–Solvent Action
CA–Colloidal Activity
WC–Water Conditioning
BI–Buffer Index
pH–Energy of Alkalinity
TA–Total Alkalinity
RE–Research and Experience, the combining factor that puts all the above elements into balance and to work on your specific problem.

HOT TANK CLEANING OF IRON & STEEL

Turco Type X, through *Surface Chemistry**, removes grease and dirt from iron and steel by hot tank immersion. Type X emulsifies, saponifies, penetrates, wets out adhesive soils, and conditions hard water. Extremely economical and easy to use.

CORROSION AND SCALE REMOVAL

Turco De-Scaler, through *Surface Chemistry**, removes heavy deposits of carbonate scale in cooling systems, radiators, and boilers. Turco De-Scaler is a heavy duty compound which dissolves scale without attack on the underlying metal.

Turco W.O.#1 – Corrosion and Rust Remover, Through *Surface Chemistry**, W. O. #1 removes rust, stains and corrosion without injury to metal. Prepares metal for lasting paint adhesion. Passivates, neutralizes and prevents rust formation beneath paint. Gives a good tooth to which paint easily adheres.

PREPARING ALUMINUM FOR SPOT WELDING

Turco Agiton is a hot tank aluminum cleaner built to provide the highest possible degree of cleaning energy consistent with perfect safety. It withstands considerable agitation without foaming, removes identification markings and zinc chromate primer, along with grease and oil.

Turco Vulco Etch chemically prepares aluminum surfaces for sound, *uniform* spot welding. A revolutionary cold treatment, carefully controlled in action. Simple to use. Nonhazardous to materials and personnel.

Specialized for the metal working industries, Turco methods and materials cut costs, speed production, guarantee a clean surface no matter what the contamination

Turco has developed many of the finest and most efficient cleaning materials and methods in the country – for gigantic industrial plants – for the Armed Forces – as well as for small one- or two-man operations.

From this experience have come hundreds of specialized industrial cleaning compounds and a wealth of know-how that will help you in your business, regardless of the materials and methods you are now using. Following are a few of hundreds of Turco compounds that will not only help increase the quality of your work, but which will also save you manpower and cut your overhead. A Turco Field Representative will be glad to demonstrate any or all of these products.

PREPARING METAL FOR PLATING

Turco Prosolv B is a remarkable electrolytic plater's cleaner which produces "chemically clean" surfaces. It is approved for stripping tin deposit in the Bullard-Dunn Process, is substantially anhydrous, and completely soluble in hot or cold water. Prosolv B penetrates deeply, contains no soap, is free rinsing.

Turco De-Scaler, used as a pickle before plating, produces smooth, bright, unpitted iron and steel surfaces. Fast acting, thorough, but carefully inhibited against attack on sound metal.

Turco Acryl is a positive inhibitor against attack on metal in acid pickling baths. It is ideal in muriatic or sulphuric vats, either hot or cold. It is completely soluble, nonfoaming, nonpoisonous and noninflammable–saves acid and metal. Safeguards health of workers.

PREPARING METAL FOR ANODIZING, CHROMATIZING AND PHOSPHATIZING

Turco Airlion 81V, an alkaline hot tank material for cleaning aluminum. Airlion 81V produces a solution of intense alkalinity–yet, is harmless to aluminum. It absolutely harmless to aluminum. It cleans by wetting out, rinses freely and leaves a "chemically clean" surface.

GALVANIZING

Turco offers several compounds which, through *Surface Chemistry**, save time and manpower and prevent rejects. For example, *Galvo*, a hot tank cleaner that removes oil, paint and grease from structural steel preparatory to galvanizing; *Type X* and *Turco De-Scaler* previously described; and *Turco Redi-Paint*, a cold preparation which acts instantly–makes paint stick to galvanized surfaces.

COMPLETE INFORMATION AND DEMONSTRATIONS

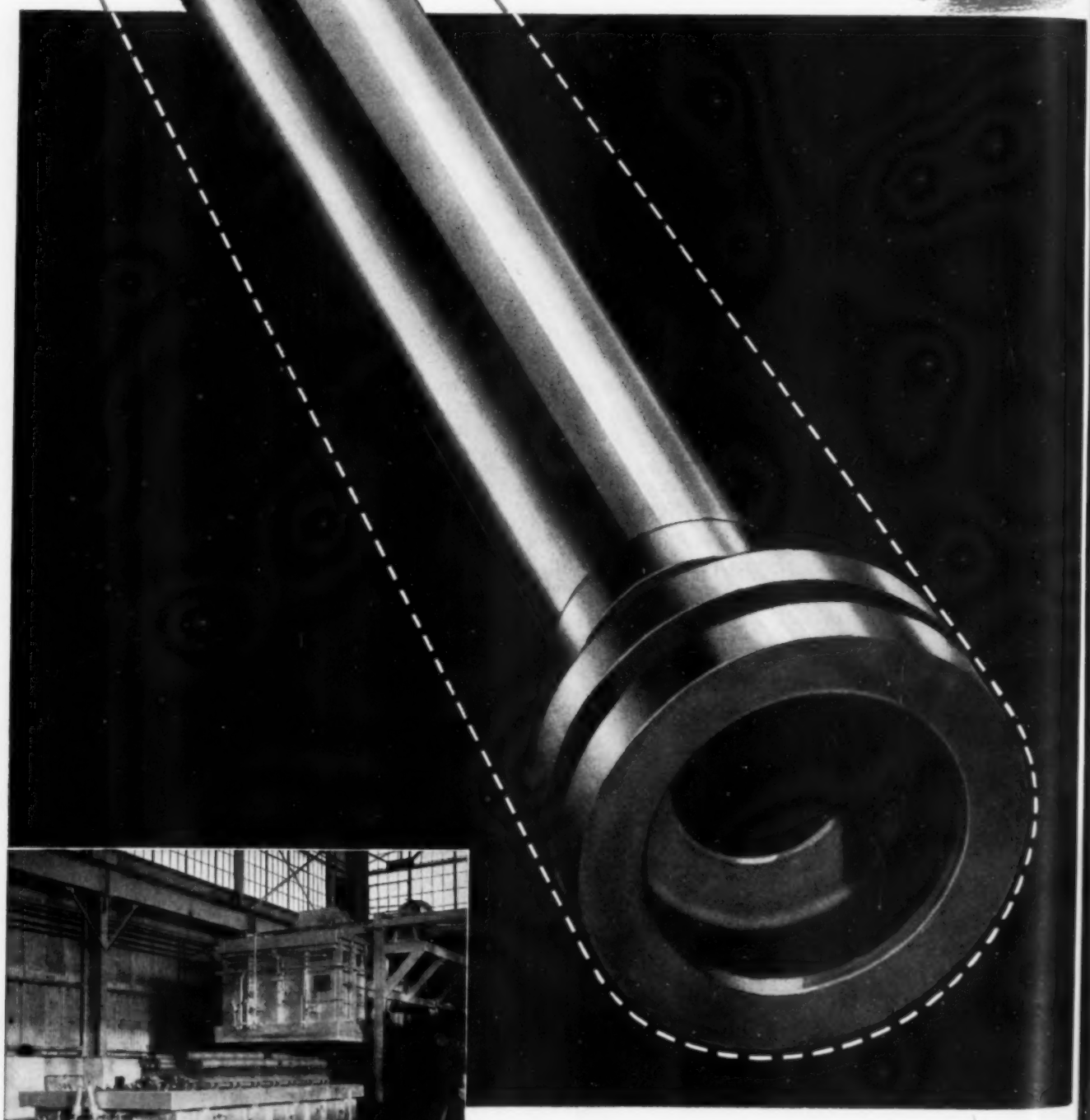
It will pay you to get Turco's suggestions. Write on your letterhead for details about any of these Turco cleaning compounds, or for free demonstrations in your own plant. Address Turco, Department MP-12.

TURCO

INDUSTRIAL CLEANING COMPOUNDS

TURCO PRODUCTS, INC. *Main Office and Factory:* 6135 S. Central Ave., Los Angeles 1
Offices and Factories: 125 W. 46th St., Chicago 9 · 1606 Henderson St., Houston 1, Texas
New York Office: 415 Greenwich St., New York 13 · *Offices and Warehouses in All Principal Cities*

CUTTING AWAY 85% CALLS FOR "TOP"



Because of the increase in machinability effected by heat treatment, Republic has increased capacities to supply your every need in furnace treated cold drawn steels—annealed, normalized, spheroidized, stress relieved or otherwise heat treated.

OF THE ORIGINAL STEEL BAR

MACHINABILITY

The hydraulic cylinder piston at the left was made from a 2½" round steel bar (NE-8630)—machined to shape on a turret lathe, drilled at both ends and tapped at one end. It then was heat treated to 125,000 lbs. per sq. in. minimum tensile strength, ground and polished, chrome plated and again polished.

But of greater importance is the fact that in producing this part it was necessary to machine away 85% of the original bar. That called for "top" machinability—an important reason why Republic Union Cold Drawn Steel was used.

For more than half a century, the words "UNION DRAWN" have stood for UNIFORMLY HIGH MACHINABILITY—without sacrifice of surface, physicals, soundness, tolerance, response to heat treatment or other qualities.

During these 50 years, intensive laboratory research and unequalled experience acquired in parts producers' plants have resulted, time and again, in improvements in the machinability of Republic Union Cold Drawn Steels. And as new ways for further increasing machinability are discovered, they will be applied to these steels.

If machinability is a vital factor in your production, Republic Union Cold Drawn Steels may be just what you need to step up efficiency and increase output—to benefit from faster speeds, heavier feeds and longer tool life. Republic metallurgists are ready NOW to help you produce better steel parts at lower unit cost.

REPUBLIC STEEL CORPORATION
Union Drawn Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N. Y.

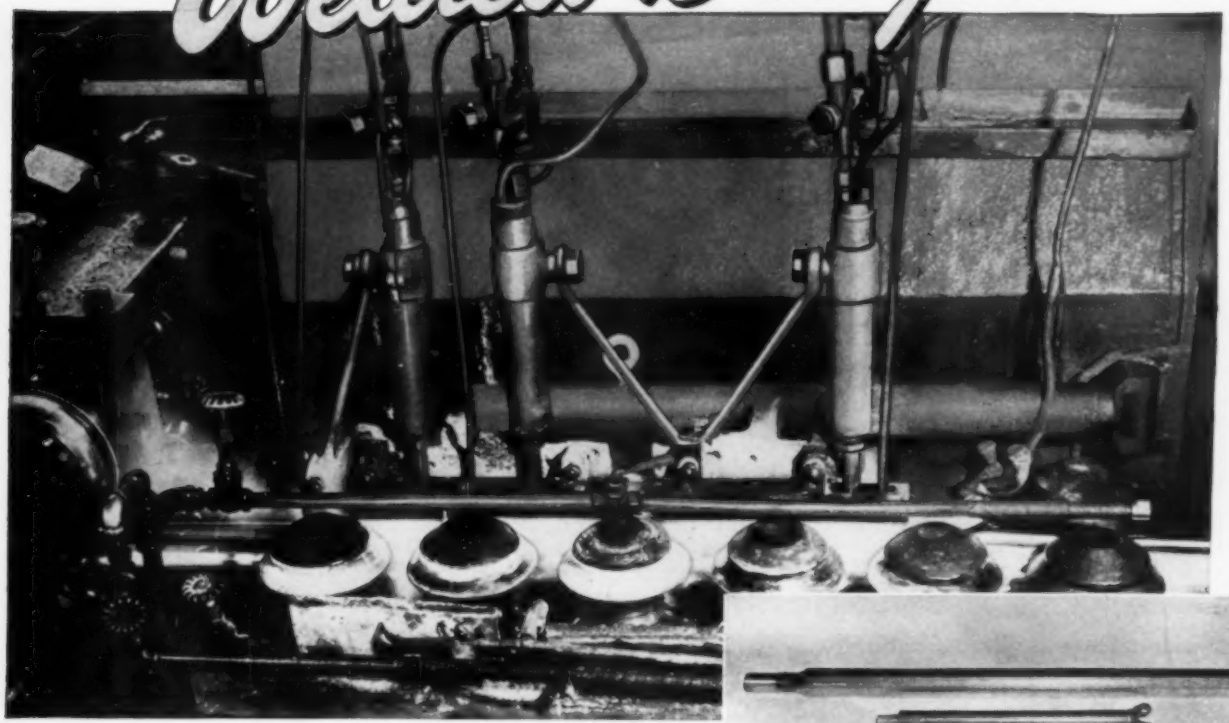
Republic

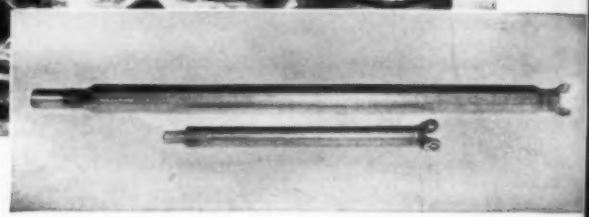
UNION COLD DRAWN STEELS

Reg. U. S. Pat. Off.

Free-Machining Bessemer, Open-Hearth and Electric Furnace Steels
•
Union Cold Drawn Special Sections
•
Union Cold Drawn and Ground Rounds; Turned and Polished Rounds; and Turned, Ground and Polished Rounds (Union Precision Shafting.)

Welded Design





Universal drive shafts, now being used in ordnance products, illustrate the severe service which oxyacetylene welded tubing withstands.

SAVES TIME . . .
CONSERVES MATERIAL . . .
SPEEDS-UP DELIVERIES

In aircraft, ordnance, construction, shipbuilding, and thousands of contributing plants, innumerable parts are now being built better — stronger — and quicker than ever before . . . with greater savings in money and material . . . because manufacturers are using one or more of the many oxyacetylene processes.

As an outstanding example — steel tubing is oxyacetylene welded at rates up to 200 feet per minute. Formed from flat strip of proper width, then high-speed welded on a continuous tube welding mill, this tubing meets such tough service requirements as torque shafting in Army tanks . . . in fact any application where a premium is placed on light weight and strength.

So, if you are planning a product that requires maximum strength . . . durability . . . lightness . . . with greater production economy and speed, design it for welded construction. Air Reduction's nationwide Applied Engineering Department and its research facilities are at your disposal to supply the "know how" information on any design problem involving the use of the oxyacetylene flame and the electric arc.

Call your nearby Airco office today, or write: Dept. MP, Air Reduction, General Offices, 60 East 42nd Street, New York 17, N. Y. In Texas: Magnolia Airco Gas Products Company, General Offices, Houston 1, Texas. Represented Internationally by Airco Export Corporation.

AIR REDUCTION

OFFICES IN ALL PRINCIPAL CITIES

ORIGINATORS OF MODERN OXYACETYLENE FLAME AND ELECTRIC ARC METHODS FOR METAL FABRICATION

AIRCO

MASTERS OF PRECISION

Better Metals for Many Uses

Precision-made brass and other Western copper-base alloys will serve important functions in a large number of tomorrow's new and improved products. Manufacturers seeking alloy metals to meet very exacting requirements find that Western, with mills at East Alton, Ill., and New Haven, Conn., delivers *as specified* . . . in sheet, strip, long coils or stamped parts.

We may be able to serve you now. We would appreciate an opportunity to discuss your requirements for brass and other copper-base alloys.

WESTERN BRASS MILLS

DIVISION OF OLIN INDUSTRIES, INC.

East Alton, Illinois

BRASS • BRONZE • PHOSPHOR BRONZE • NICKEL SILVER • COPPER

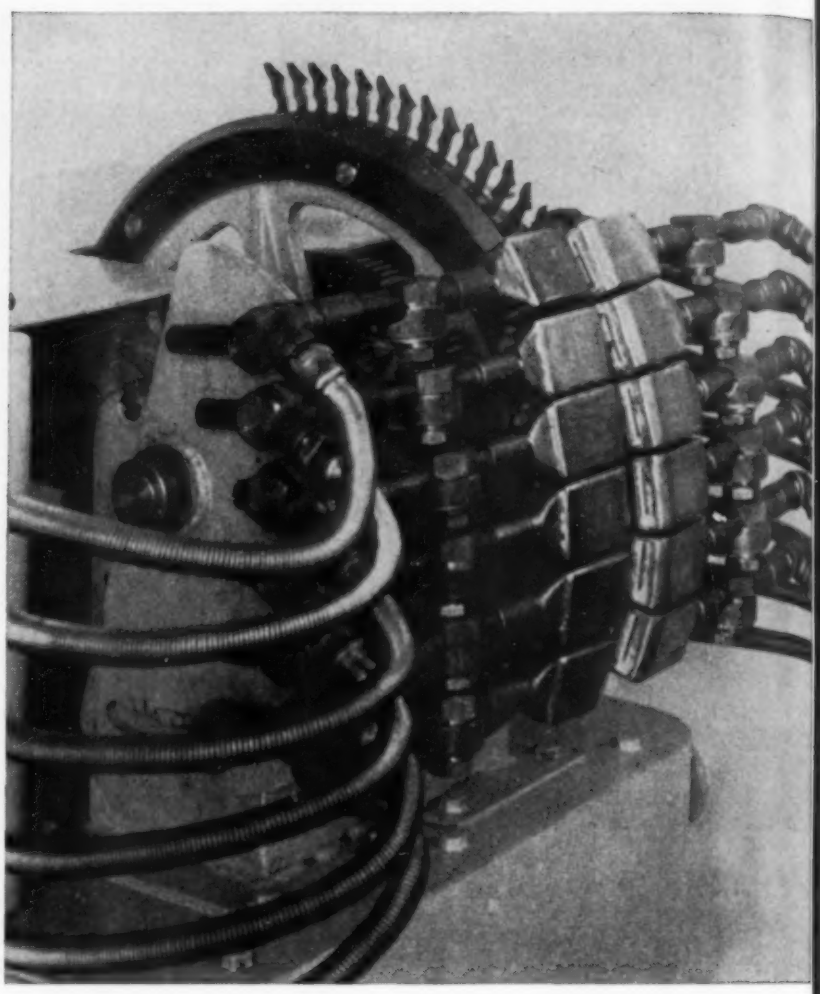
December, 1945; Page 1233

GAS, OUR MOST *versatile* FUEL, *helped saw our way to Victory*

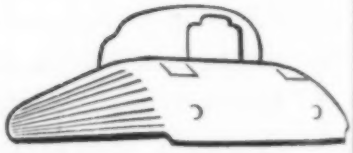
Our troops, moving through tropical forests, found it often necessary to cut down trees of the tough teak family—to make passage or perhaps to use this sturdy timber for their needs. To saw down these trees required a cutting edge that could indeed, not only "take it" but "deal it out."

Sawteeth or bits are removable; they must be extremely hard at the edge, soft and ductile where they are attached to the band of the saw. This calls for specially well controlled heat treating of the part. Gas and modern Gas heat treating equipment solve the problem.

On a circular track they run the gauntlet of 12 slot-type, ceramic cell burners, emerging with exactly the qualities demanded by their stern use. This furnace, operated by a girl, can heat treat 2,000 saw bits per hour, is adaptable to the heat treatment of many other small parts, bringing to bear an intensity of focused heat just where it is needed.



Conversely, in a mid-west plant, Gas furnaces did a most successful job of heat treating large hull castings of tanks, 22 feet long and 10 feet wide. That's a far cry from saw bits but Gas takes both extremes in its stride. Why not let the Industrial Engineer of your local Gas Company check over your heat treating problems—let him put this versatile, modern fuel to work for you.

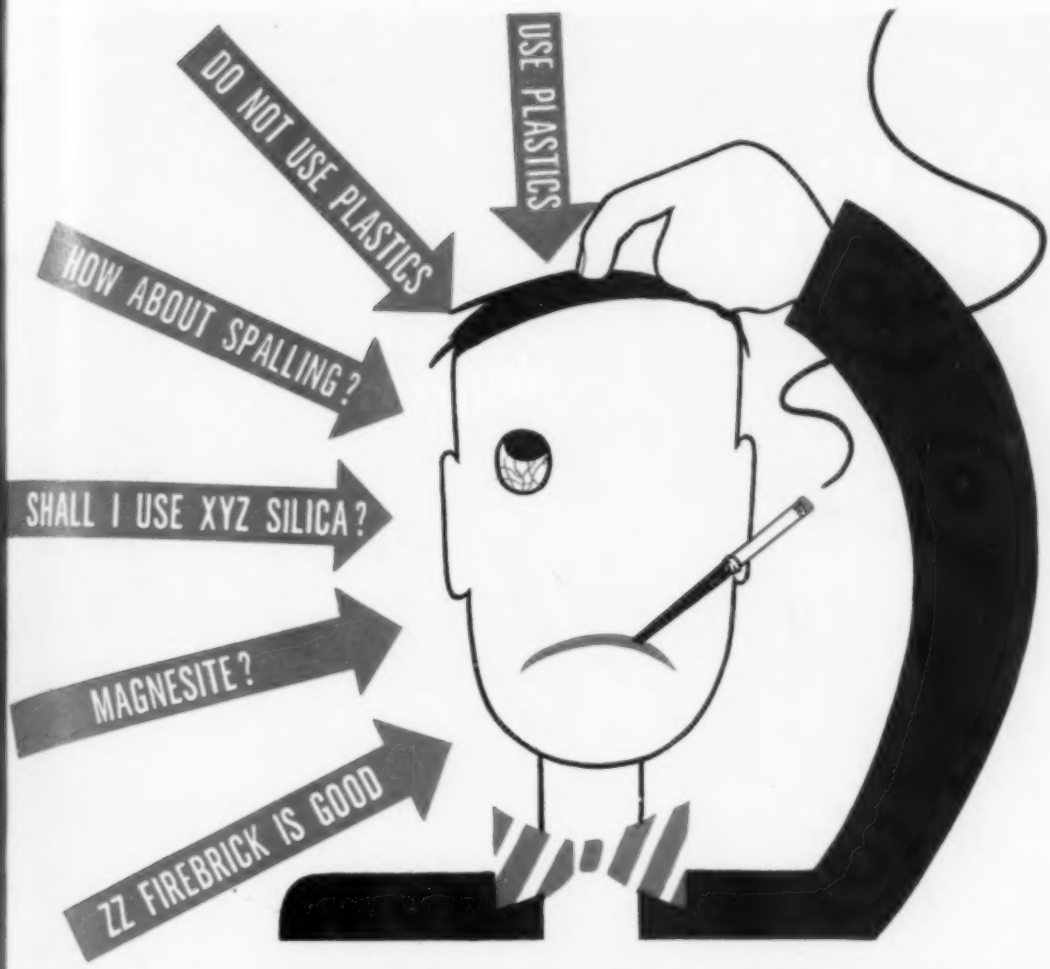


AMERICAN GAS ASSOCIATION

420 Lexington Avenue, New York 17, N. Y.

THE TREND IS TO GAS

FOR ALL INDUSTRIAL HEATING



MUDDLED?

Better refractories are being made every day, BUT the selection of refractories for most high temperature furnaces is essentially a compromise. No one type or brand of refractory will excel in all of the essential chemical and physical properties. Get 'confusion relief' by drawing on our experience of 80 years in trouble shooting refractory problems. A Taylor field engineer will be glad to go into a huddle and eliminate your muddle.

CHAS. TAYLOR SONS Co.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U. S. A.

MECHANICAL Progress

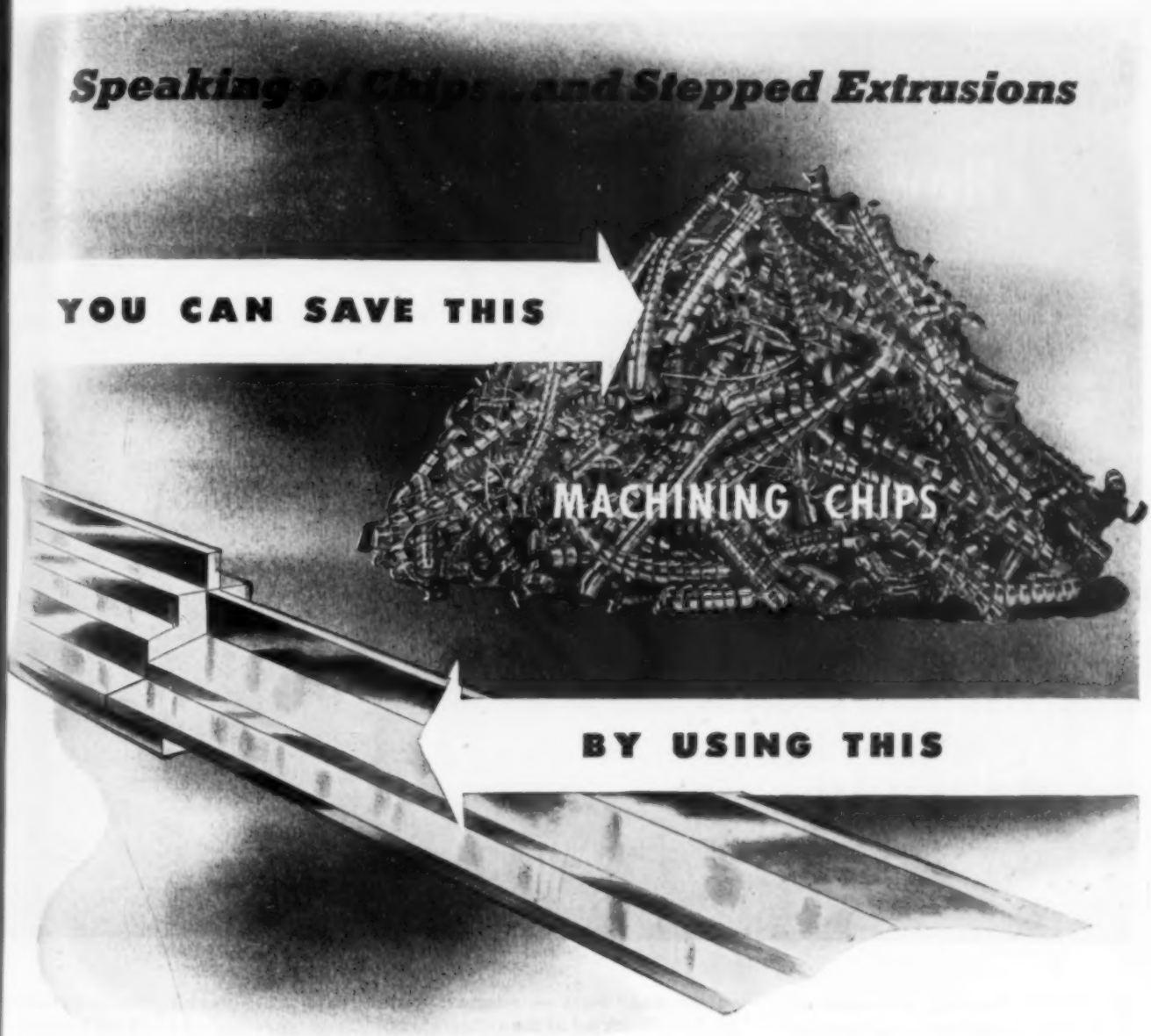
POWERED BY SPRINGS

IN the files at the Barnes plant is the spring history of almost every great mechanical contribution. Here is the story of the automotive valve spring, the aircraft engine valve spring, the typewriter spring, the refrigerator spring—and today, the helicopter spring, the radar spring, the bomb-sight spring.

Blue prints and "specs" are the tangible record of these developments—but only in the memories of Barnes craftsmen and engineers are the hours of experiment and research from which grew the final, smoothly functioning springs.

Responsibility that comes with long and close associations imposes an obligation to explore and develop the scope of spring performance—not only for present purposes—but for new milestones in mechanical progress—whatever they may be.

WALLACE BARNES COMPANY DIVISION OF ASSOCIATED SPRING CORPORATION BRISTOL, CONNECTICUT, U. S. A.



Where structural parts must be large at one end and small at the other, that's where Alcoa stepped extrusions come into the picture . . . speeding production, reducing costs. Stepped extrusions offer an advantage over conventional uniform sections by eliminating excessive machining.

How about the shapes and parts you use? Alcoa engineers will gladly discuss your designs, and offer you the benefit of their experience with extruded shapes. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh 19, Pennsylvania.

ALCOA FIRST IN ALUMINUM

ALCOA ALUMINUM

How to Slash Pier Costs in Normalizing Furnaces

IF YOU'RE looking to lower operating costs for a high temperature furnace, here's a tip from a large Chicago foundry.

On a car-type normalizing furnace, they slashed their costs by installing "CARBOFRAX" silicon carbide piers—piers that are still in excellent condition after sixteen months of service—piers that have already given a life eight times that of fireclay.

THE OPERATION: Four alloy grids, each loaded with five tons of steel castings, are used per car. The charge is placed in a normalizing furnace and brought up to 1650°—1750° F. This temperature is held for eleven to twelve hours. The car is then pulled and cooled in the air.

"CARBOFRAX" PIERS vs. FIRECLAY: Each grid is supported at the corners with "CARBOFRAX" piers. After a service of sixteen months, these piers are still in excellent condition. Fireclay piers installed in the more protected center position require replacement after two months' use due to thermal shock which results in spalling and cracking. And with "CARBOFRAX" piers the heat is more uniformly delivered to the lower section of the load.

RESULTANT SAVINGS: The cost per day for the "CARBOFRAX" piers has not as yet been determined because the first "CARBOFRAX" supports are still on the job. But their service when photographed had reduced pier costs about 66 per cent as compared to fireclay piers.

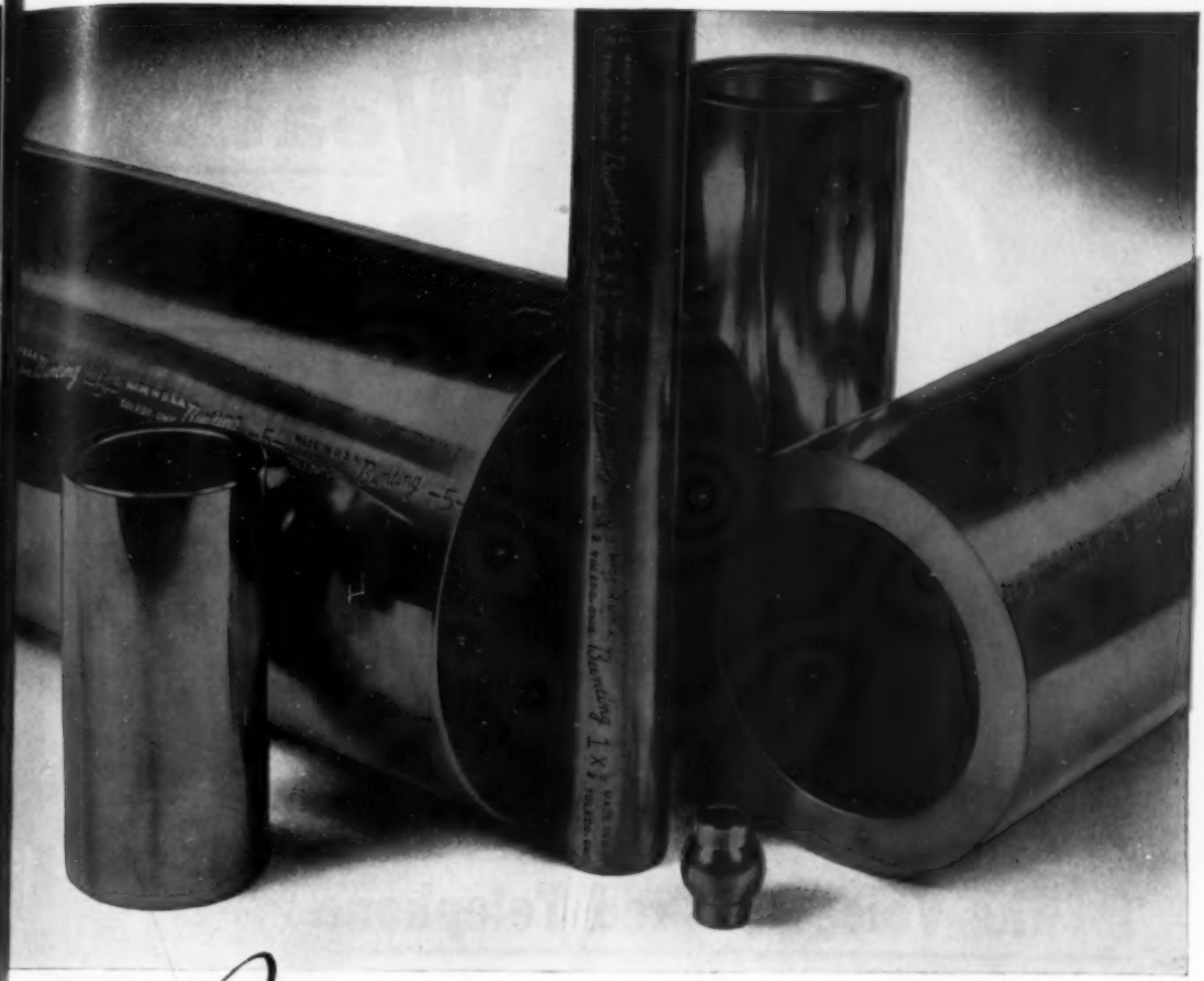
The high hot strength, excellent resistance to cracking and low spalling tendency of the "CARBOFRAX" tile have made these results possible. Even the additional abuse caused by crane-loading the car does not adversely affect the "CARBOFRAX" piers.

Let our Refractories Engineers show you how Super Refractories by "CARBORUNDUM" can boost your production and slash your operating costs. The Carborundum Company, Refractories Division, Dept. M-8, Perth Amboy, N. J.

CARBORUNDUM
TRADE MARK

"CARBORUNDUM" and "CARBOFRAX" are registered trade marks of, and indicate manufacture by, The Carborundum Company.

Super Refractories by CARBORUNDUM
TRADE MARK



Recognized advantages of Bunting Cast Bronze Bearings and Bars are maintained and increased by advanced metallurgy and manufacturing processes. These finer bronze bearings and bars are available in many different stock sizes from Authorized Bunting Distributors everywhere. Ask your Distributor for Catalog giving complete listing. For Special bearings, to your own dimensions and alloys, write our factory direct. The Bunting Brass & Bronze Company, Toledo 9, Ohio. Branches in principal cities.

30

Bunting

BRONZE BEARINGS ☆ BUSHINGS ☆ PRECISION BRONZE BARS

Weather Beater

for the Voice-powered Telephone

THE sound power telephone, an instrument requiring neither batteries nor outside current for its operation, is one of the best of this war's brain children. Materialwise, however, it is something of a problem child.

Action with planes and ships exposes it constantly to the evils of the elements . . . especially corrosion. One of the largest manufacturers of sound power telephones—RCA Victor Division of the Radio Corporation of America—uses Riverside *Phosphor Bronze* for electrical contacts and springs, retaining spring for magnet and coil, switch blades and cable guard. Resistance to corrosion, electrical conductance, and ease of fabrication are good reasons why.

Let us tell you more about Riverside *Phosphor Bronze*, and *Nickel Silver* and *Beryllium Copper*, Riverside's 3 principal alloys. Catalogs on each or all are yours for the asking.

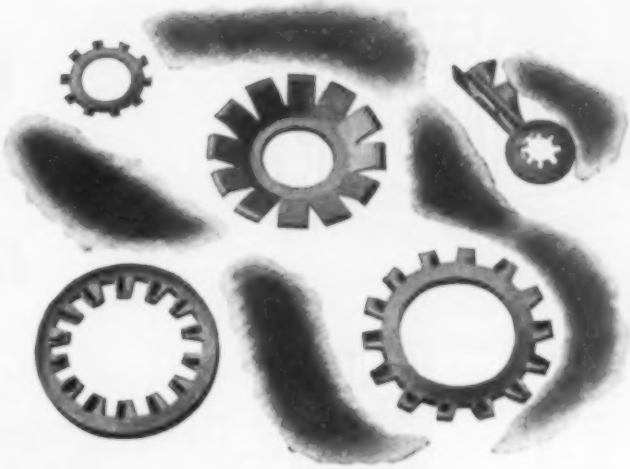
INSIDE RIVERSIDE—*Recently we put to work in our mill the latest word in continuous strip strand-annealing furnaces. From it you can expect more uniformity of anneal, better surface condition and closer gauge tolerances. This is news. But it's no news that Riverside is always looking for technical improvements. Anything which promises improvement in quality or in casting, rolling, drawing, annealing or pickling methods will get an audition at Riverside.*

RIVERSIDE

THE RIVERSIDE METAL COMPANY

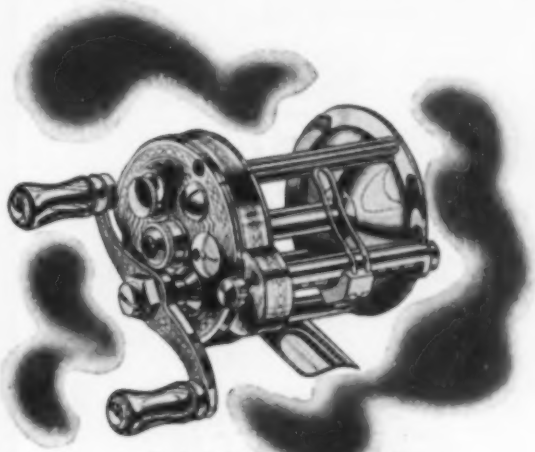
NEW YORK CHICAGO RIVERSIDE • NEW JERSEY HARTFORD CLEVELAND

RIVERSIDE PHOSPHOR BRONZE ALLOYS — Copper-tin alloys to which phosphorus is added. Made in variety of wrought and malleable alloys; special leaded mixtures; in non-malleable cast and turned rods for bearings and bushings. PROPERTIES—Wide range of tensile strengths and hardnesses. In general, phosphor bronze is a good electrical conductor, non-magnetic, and has a low coefficient of friction. It is easy to machine, can be welded by carbon or metal arc (there's a special alloy for flame welding), can be brazed or soldered. Easy to punch, draw, stamp, or spin. Phosphor bronze is rustless and resistant to corrosion, fatigue and wear. Supplied in sheets, strips, wire, rods, circles, bars, blanks or ingots.



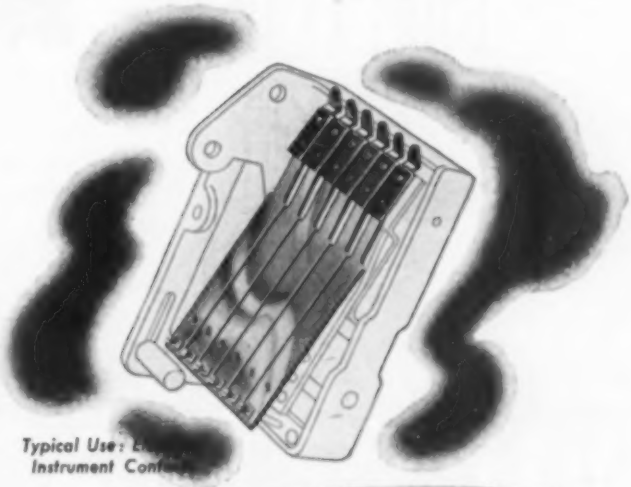
Typical Uses: Lock Washers

RIVERSIDE NICKEL SILVER ALLOYS — A combination of copper, nickel and zinc in various proportions. Made in variety of alloys, tempers, anneals; and in free-cutting alloys. PROPERTIES—Vary according to alloys. Tensile strengths up to 160,000 p.s.i., elongations up to 50%. Nickel silver is valued electrically for its specific resistance, and physically because of its clear-through silvery white appearance. In general, it is tough, resistant to wear, fatigue, and corrosion. Easy to machine in any manner, weldable by all methods, can be brazed or soldered and is extremely workable. Readily formed, bent, drawn, stamped, punched, embossed or spun. Supplied in sheets, strips, wire, rods, circles, bars, blanks and ingots.



Typical Use: Fishing Reel Parts

RIVERSIDE BERYLLIUM COPPER — an alloy with an unusual combination of properties — Unusually high strength. Excellent hardness, wear resistance and corrosion resistance. High thermal conductivity, good electrical conductivity. Easy to braze, solder, punch, draw or stamp. Can be cold worked. Outstanding for hot working qualities. Can be easily hot forged or hot pressed between 1050° and 1425°F., and heat hardened to achieve strengths rare to non-ferrous metals and alloys. Great resistance to fatigue under action, which is pronounced at high temperatures where other non-ferrous materials might fail. Negligible creep or hysterisis. Non-magnetic qualities. Supplied in sheets, strips, wire, rods, bars and blanks, usually, semi-hard, cold worked for fabrication and heat treatment.

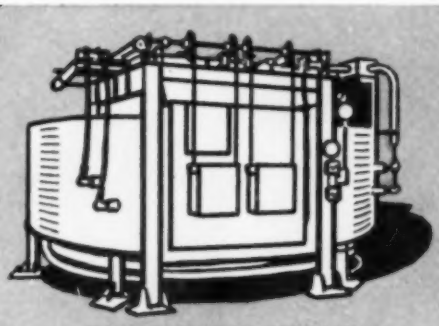


Typical Use: [illegible] Instrument Con[illegible]

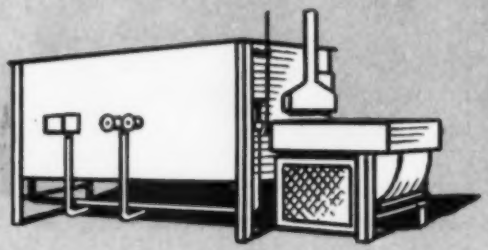
Also special alloys of copper, zinc and tin for specific purposes

PHOSPHOR BRONZE
NICKEL SILVER
BERYLLIUM COPPER

HOW TO HEAT-TREAT HIGH-SPEED STEELS *without decarb*

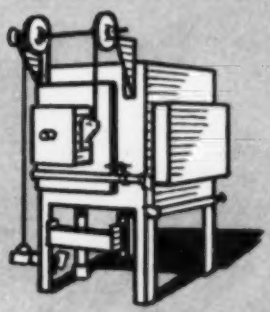


ROTARY-HEARTH FURNACE

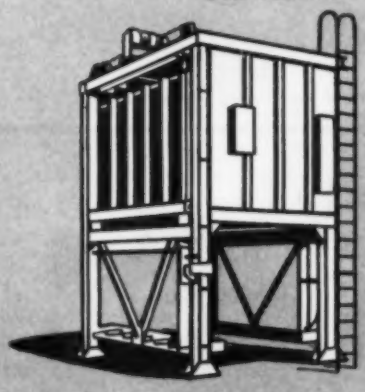


CONVEYOR FURNACE

PIT FURNACE

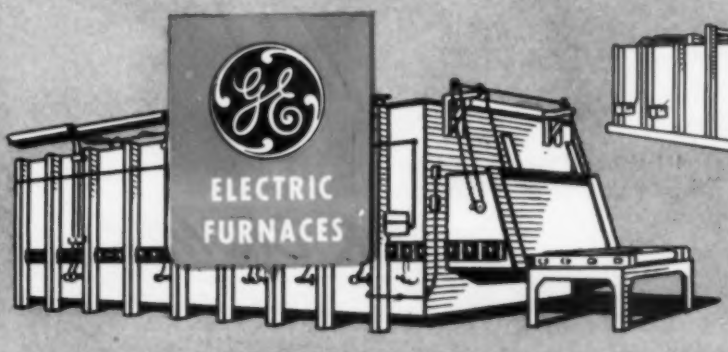


BOX FURNACE



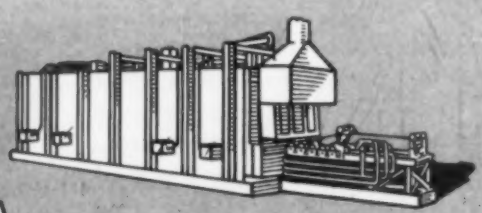
ELEVATOR FURNACE

1. High-speed steels of all types—moly, tungsten, or cobalt—can be heat-treated in G-E electric box furnaces without the formation of scale and with *no* decarburization. A typical installation consists of a preheat and a high-heat furnace, as installed here in an ordnance plant.

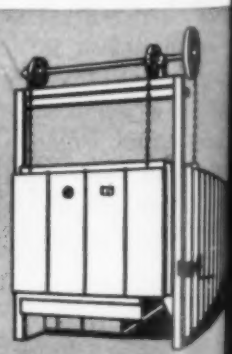


ROLLER-HEARTH FURNACE

GE ELECTRIC FURNACES

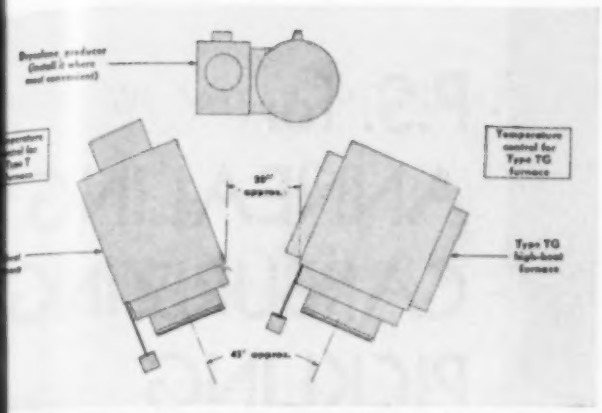


PUSHER FURNACE

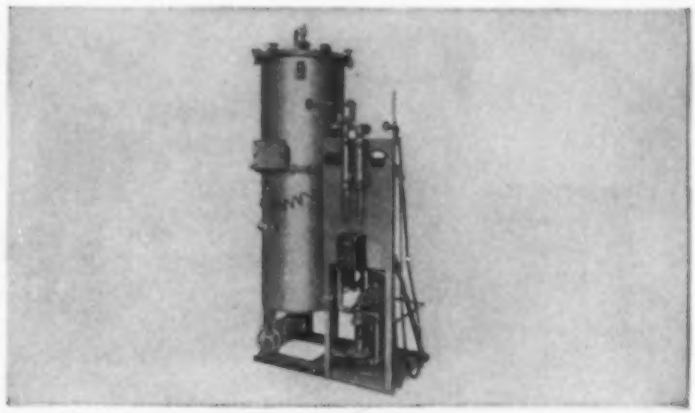


CAR-BOTTOM FURNA

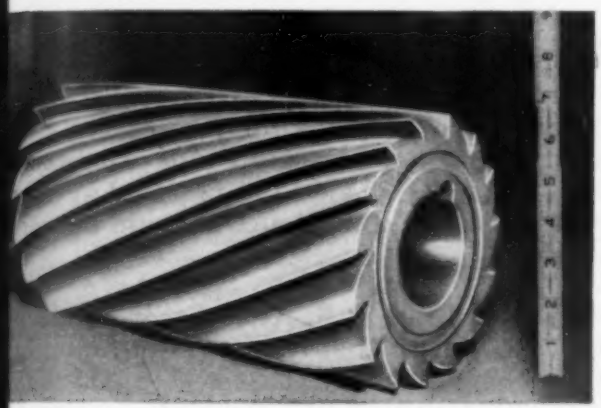
For Practically Every Industrial Need . . . Backed by a Nationwide Engineering Servi



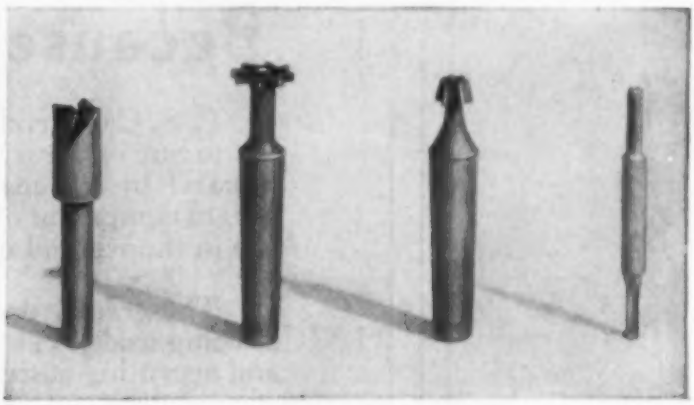
2. When the two furnaces are installed in accordance with this recommended layout, the operator, by making an easy pivot, can transfer work from the preheat furnace to the high-heat furnace without unnecessary steps. A water-quench tank can be located in front of the preheat furnace; an oil-quench tank, in front of the high-heat furnace.



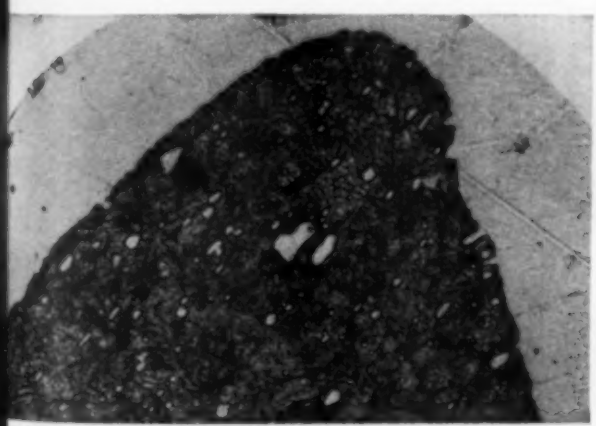
3. During the heat treatment of high-speed steel, a protective atmosphere, free of carbon dioxide and water vapor, must be introduced into the furnace to prevent oxidation and decarburization of the steel. Such an atmosphere is created by the processing of standard fuel gases and air in this specially constructed, 200-cfh, G-E drycolene producer.



4. This sturdy, slab-milling cutter of Bethlehem No. 66 high-speed steel was made to size before heat-treating. It was given a first preheat at 550 F in air, a second at 1550 F in drycolene, and a high heat at 2250 F in drycolene plus propane. There was no decarb, and edges were file hard.



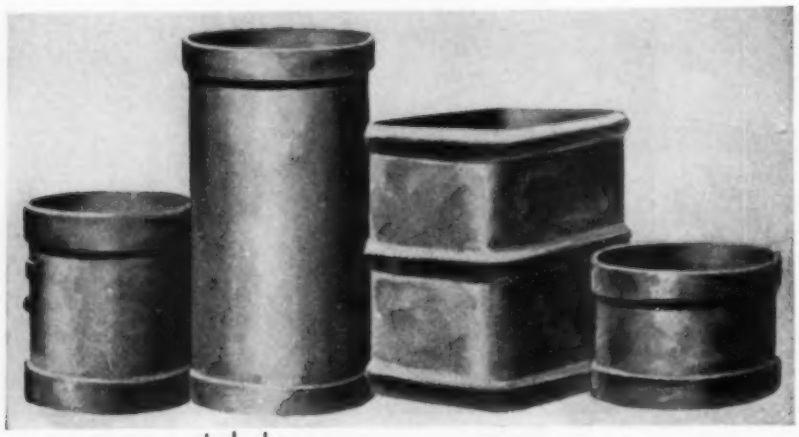
5. In cutters such as these, of moly and cobalt high-speed steels, both sharp cutting edges and sharp corners must be maintained. After heat treatment in a G-E Type TG box furnace, in drycolene atmosphere, the cutters were free of scale and decarb; both cutting edges and corners were file hard.



6. The cutting edge of the moly-cobalt, high-speed tool in this photomicrograph (X-500) clearly shows the absence of decarb and the uniform distribution of carbon particles. Because the hardness extends right to the surface, no finish-grinding is necessary.

7. To advise you on an industrial heating problem, G.E. maintains heating specialists in all principal cities, plus an engineering staff qualified to recommend the *best* type of equipment for your particular purpose. For detailed recommendations, consult your nearest G-E heating specialist, or write Apparatus Dept., General Electric Company, Schenectady, N. Y.

GENERAL ELECTRIC



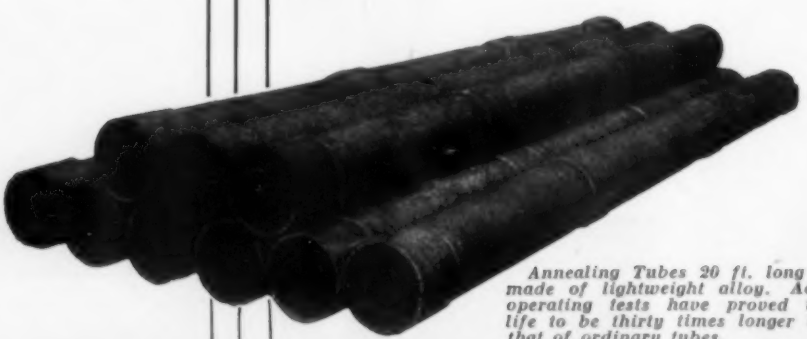
P.S. for ANNEALING CARBURIZING PICKLING

Lower First and Last Costs Because of *Lightweight*

P. S. Carburizing, Annealing and Pickling Equipment costs *less* to buy and *less* to operate. A quarter-century of progressive research by our engineers and metallurgists has resulted in lightweight equipment of sturdy design and construction without sacrifice in the wanted qualities.

The greatly decreased weight of P. S. Alloy Steel Products, as compared to cast iron, is the factor that reduces both first costs and operating costs.

If your present equipment is not functioning up to par, or you want a complete production check-up, you are invited to consult our plant analysts on your problems.



Annealing Tubes 20 ft. long and made of lightweight alloy. Actual operating tests have proved their life to be thirty times longer than that of ordinary tubes.

A special Annealing and Heat Treating Basket for use in the aviation industry. Made to your order and in a style to suit your requirements.

THE PRESSED STEEL COMPANY

of WILKES-BARRE, PENNSYLVANIA

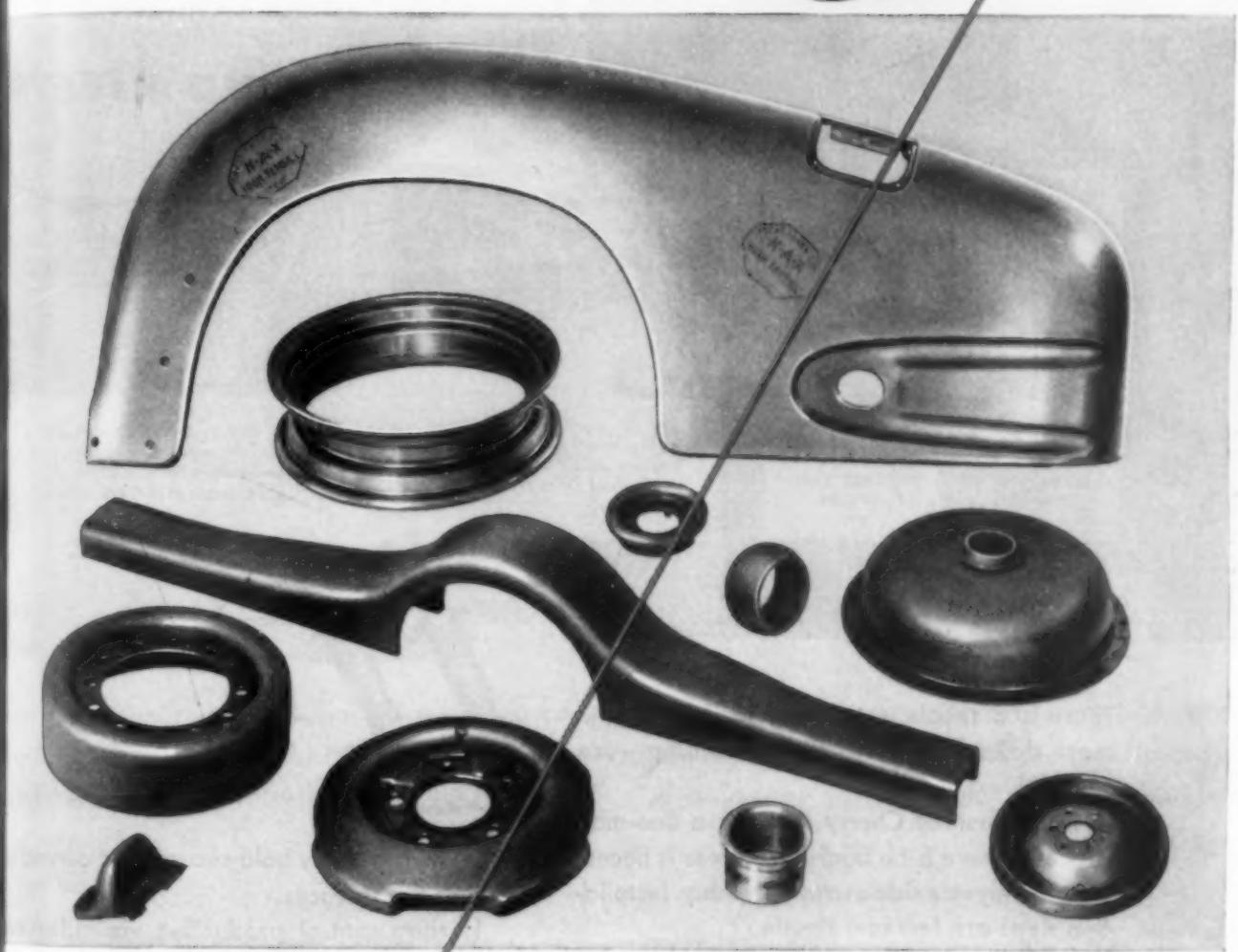
BRANCH OFFICES: 312 Curtis Bldg., Detroit; 503 Nicholas Bldg., Toledo; 1915 Engineers Bldg., Chicago; 51 E. 42nd St., New York; 1005 Sterling Bldg., Houston, Texas; A & M Accessories Ltd., 19 Melinda St., Toronto, Canada; Broad St. Station Bldg., Philadelphia; 417 So. Hill St., Los Angeles.

PRESSED STEEL COMPANY PRODUCTS: Carburizing and Annealing Boxes, Thermocouple Protection Tubes, Seamless Steel Cylinder Caps, Seamless Steel Neck Rings, Welded Alloy Tubing for High Temperature and Corrosive Applications, Radient Tubes, Inner Covers and Base Sheaths for Steel Mills

WHEN WE SAY *EXCEPTIONAL FORMABILITY*...

here's what we mean!

N-A-X
HIGH-TENSILE STEEL



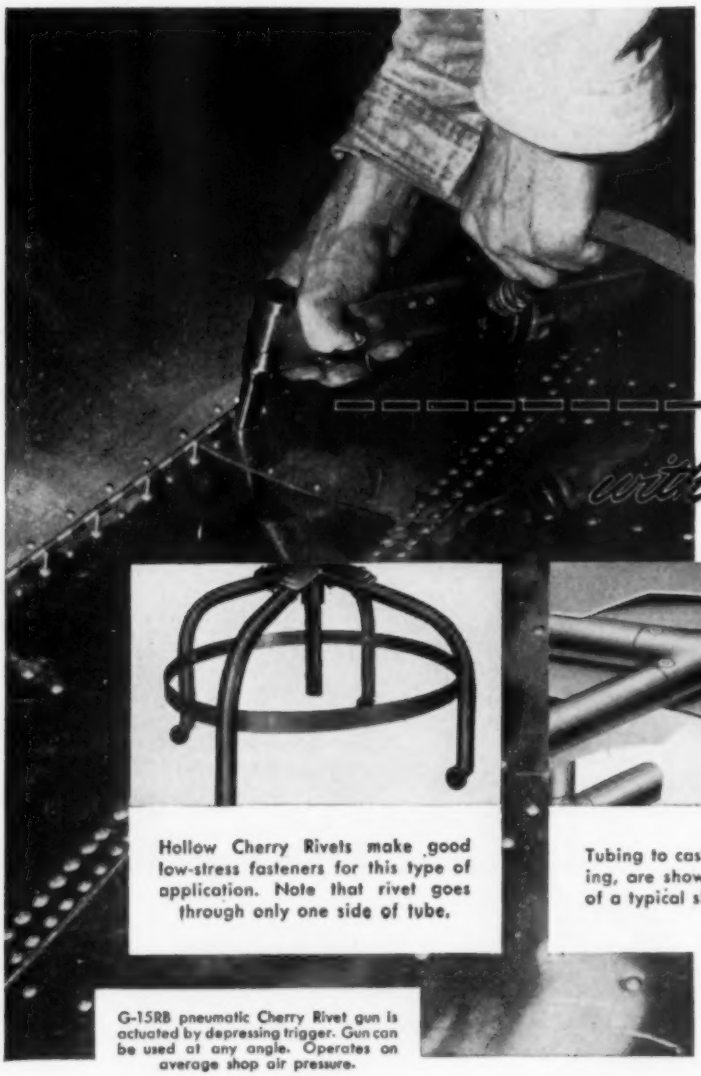
These are not an artist's conception of shapes that can be fabricated with a high-strength steel. They are actual parts produced with *N-A-X High-Tensile* by manufacturers who have learned that *great strength and exceptional formability* are available in one great steel. ¶ If you have a problem that involves the fabrication of high-strength steel—if you have a product that could command the market if it were stronger, longer-lasting or lighter—consult Great Lakes Steel Corporation.

GREAT STEEL FROM GREAT LAKES

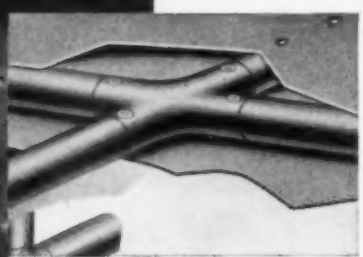
GREAT LAKES STEEL
Corporation
N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
UNIT OF NATIONAL STEEL CORPORATION

SHEET METAL FASTENING *simplified and speeded up*

with **CHERRY BLIND RIVETS**



Hollow Cherry Rivets make good low-stress fasteners for this type of application. Note that rivet goes through only one side of tube.



Tubing to cast elbows, metal to tubing, are shown in this cross section of a typical sheet metal installation.

G-35 Cherry Rivet gun operates simply by squeezing handles together. Pulling head is designed for easy access to difficult areas.

G-15RB pneumatic Cherry Rivet gun is actuated by depressing trigger. Gun can be used at any angle. Operates on average shop air pressure.

There is a simple, quick way to do even the most difficult sheet metal fastening—use Cherry Blind Rivets.

Installation of Cherry Rivets is a one-man process. There is no bucking. Access is necessary to only one side of any assembly. Installation steps are few and simple.

These easy-to-install rivets are upset with a controlled pulling action by small, lightweight Cherry Rivet pneumatic or hand guns.

Cherry Rivets work successfully in difficult pliable or brittle materials, as well as in all sheet metals. They hold securely on curved as well as flat surfaces.

Hard-to-control production variables are met by generous material thickness and hole size tolerances, unusual shank expansion, high clinching force.

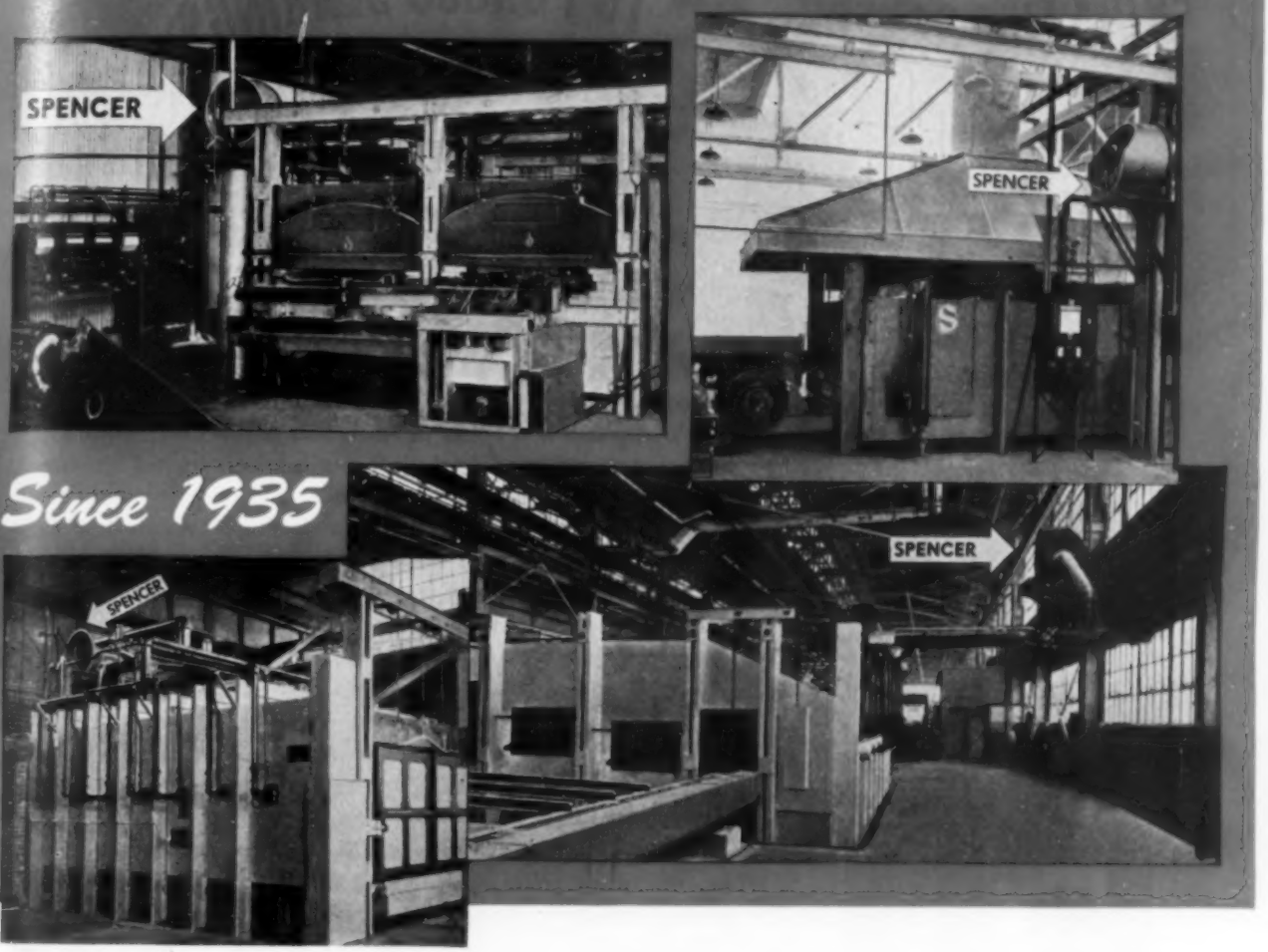
Cherry Rivets are made in several types, head styles, diameters, grip lengths and alloys. Their installed cost is not high.

CHERRY RIVETS, THEIR MANUFACTURE & APPLICATION ARE COVERED BY U. S. PATENTS ISSUED & PENDING

For additional information, ask your nearest jobber for illustrated Manual D-45, or write Dept. A-194, Cherry Rivet Company, 231 Winston Street, Los Angeles 13, California.

Cherry Rivet
Company
LOS ANGELES 13, CALIFORNIA

SALEM ENGINEERING COMPANY



Salem "Engineered Heat" has solved many outstanding problems in heat treating aluminum sheets, bars and tubes including car type furnace operations and the largest rotary forge furnace in the world.

Salem has used Spencer Turbos constantly since 1935.

In one compact unit, the Spencer Turbo combines simplicity with unusual reliability, and provides a steady flow of clean air with a constant pressure.

Power varies with the load and efficiencies are high at all loads, resulting in extremely high over all efficiencies under fluctuating service demands.

Maintenance records show that batteries of Spencers operate for years at a cost of one dollar per machine per year for repair parts. Many of the Spencers built a quarter of a century ago are giving satisfactory service today maintaining their original test efficiencies.

Special Spencer Bulletins are available as follows: Data, No. 107, Gas Boosters, No. 109, Four Bearing, No. 110, Blast Gates, No. 122, Foundries, No. 112 and the General Bulletin is No. 126.

THE SPENCER TURBINE COMPANY · HARTFORD 6, CONN.

SPENCER HARTFORD **TURBO-COMPRESSORS**

FROM LIFE SAVERS TO POROUS BEARINGS

Stokes serves Industry in a variety of ways.

It is our good fortune to have grown up with the machine age, assisting in some measure in the industrial development of America during the past half century.

Over the years we have had the privilege of working with some of the country's foremost scientists, engineers and manufacturers in developing new and better products and production methods. We have contributed our own skills in engineering original equipment. Stokes engineers pioneered equipment for making the popular "candy mint with a hole in it" — a development which demonstrated it was practical to make cored pieces on a Tablet Machine, and led to production by modern powder metallurgy of porous bearings, iron gears, cams, piston rings, and countless other vital needs of industry.

We, likewise, pioneered new high vacuum processing methods and equipment to make available absolute pressures within the micron and submicron range. Evaporation of metals and metallic salts, and impregnation of light metals are important recent applications of this process. In other fields, too, Stokes equipment is well known and widely used . . . for molding thermo-setting plastics, for manufacturing pharmaceuticals, in the field of electronics, nuclear physics and other industries.

It shall be our continuing endeavor to serve Industry well. We look toward the future with hope of rendering even greater service in the years to come. F. J. STOKES MACHINE CO., 6006 Tabor Road, Phila. 20, Pa.

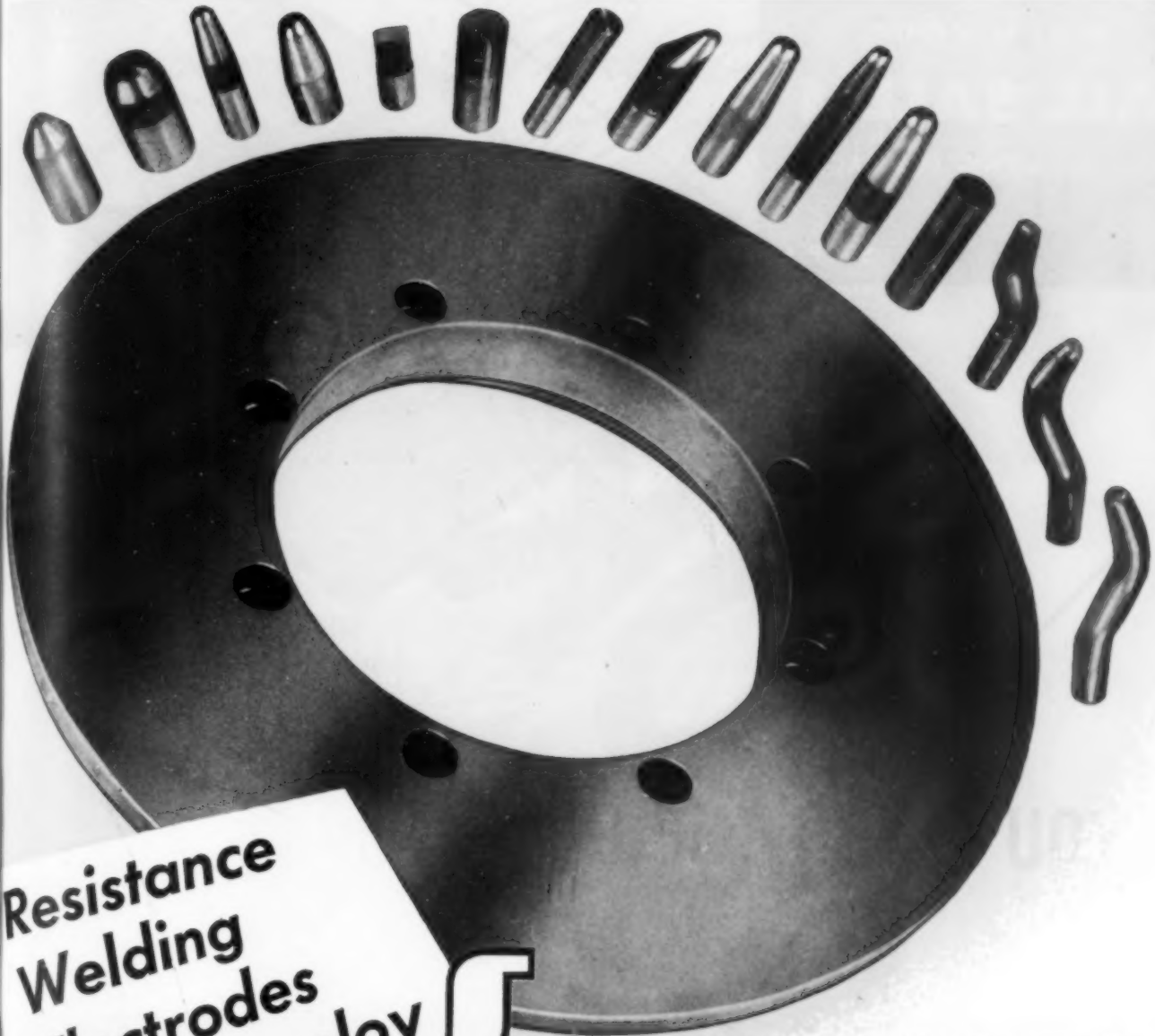
50th YEAR

of Service to Industry

F. J. STOKES

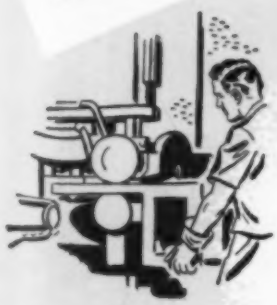
EST. 1895

Pioneering in Automatic Compression Molding of Plastics, Powder Metals Compacting, Dry-Pressed Ceramics, High Vacuum Processing, Desiccation from the Frozen State, Water Distillation, Pharmaceutical Technique and Equipment.



Resistance Welding Electrodes of Ampcoloy

give you controlled quality and uniformity . . . eliminating costly production losses



Specialists in engineering, production, and finishing of copper-base alloy parts.

In resistance welding, lack of uniformity in electrodes and wheels means "time out" to adjust current, time, and pressure settings—resulting in costly production losses.

At Ampco, control of quality and uniformity — both absolutely necessary in this exacting field — are kept under close supervision of laboratory technicians throughout the entire production cycle, resulting in increased productive time.

Ampco resistance welding products comply with all RWMA specifications. Included in the line are spot welding electrodes; seam welding wheels; centrifugally cast seam welder bushings; seam welder shafts; flash and projection welder dies; extruded and drawn rounds; and many others.

To reduce your welding costs, standardize on Ampco's line of resistance welding electrodes. You are assured of all-important uniformity . . . *consistently*. You cut "down-time" to a minimum . . . you speed production — and, finally, you get more service from each electrode. Complete details are given in Bulletin 68. Write for your copy. Your request will receive prompt attention.

AMPCO

ZW-2

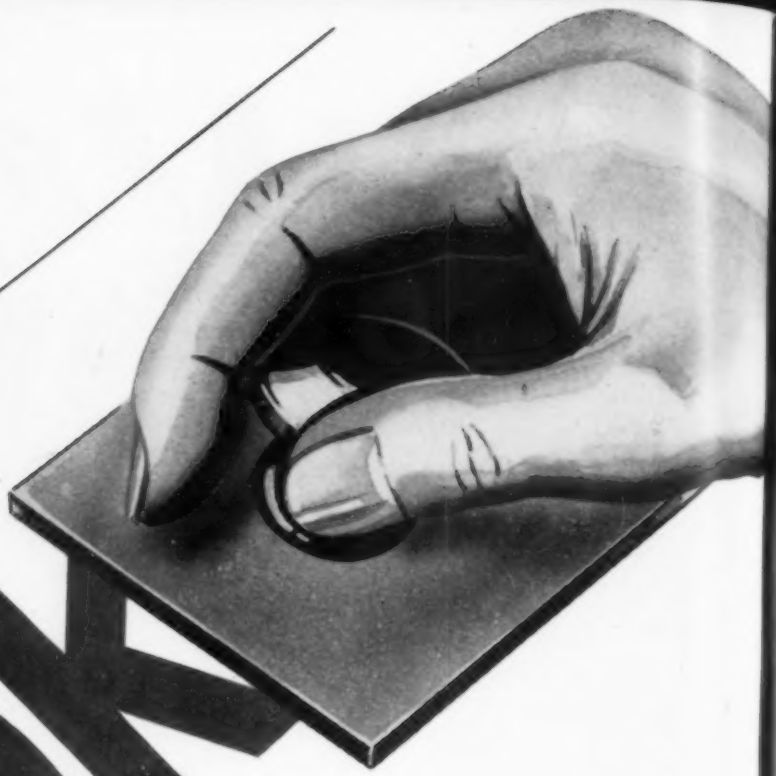
AMPCO METAL, INC., Department MP-12, MILWAUKEE 4, WISCONSIN

WHEN YOU

CALL SALEM

ABOUT HEATING FURNACES

STEP 5



OK

...YOU FLASH THE GREEN LIGHT

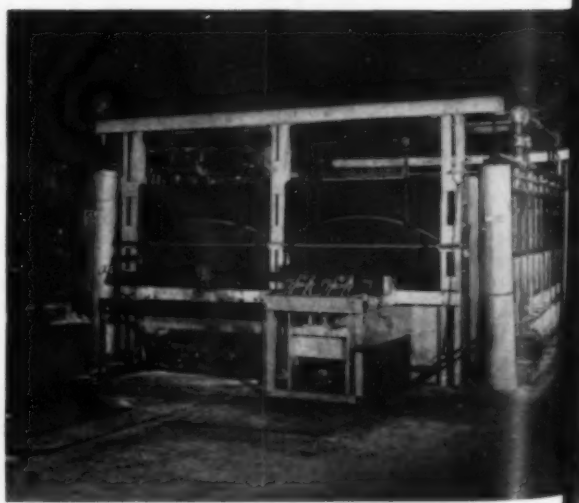
On new heating furnaces or related equipment, Salem engineers work closely with you and your staff.

After preliminary spade work, a Salem heating engineer checks over final plans and drawings with you. Before you give us the green light for construction, you have the opportunity of analyzing all details of the installation in light of your production. Thus you assure yourself of maximum efficiency in the proposed installation.

The detailed preliminary planning embraces exchange of ideas between you and Salem's heating men, preparation of visual roughs, testing, and the incorporation of new innovations you want for lowest cost operation.

Production efficiency, as you well know, depends upon thoroughness of planning and workmanship. Salem's step by step planning gives you the kind of heating installation you want for competitive production.

CALL SALEM, originators of Engineered Heat and builders of the world's largest rotary forge furnace, for any type, size, or style of heating furnace or related equipment.



NOTE: Write for Salem's new 16-page, illustrated booklet—"Engineered Heat," complete with easy-to-use heating and temperature charts.

Engineered Heat

SALEM

ENGINEERING COMPANY

SALEM, OHIO

Simplify your Product Fabrication with

SUPERIOR STAINLESS STRIP COILS

. . . . LONG LENGTHS, UNIFORM COMPOSITION, TEMPER AND DIMENSION

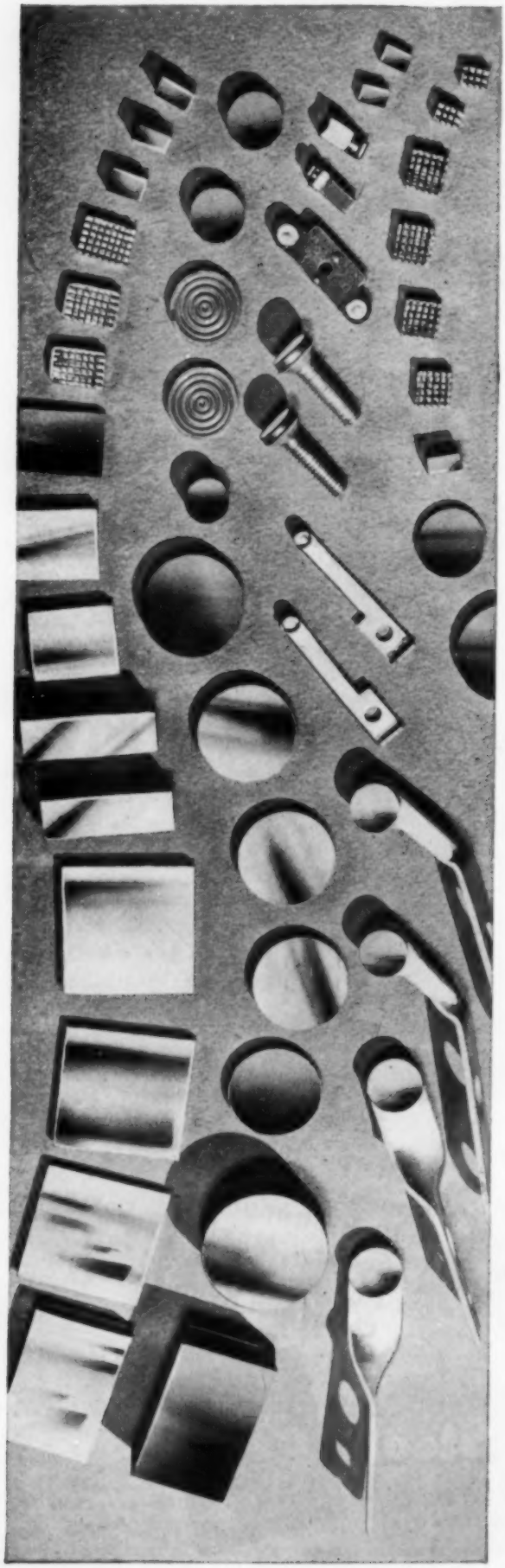
Plus

All the Inherent Advantages of Stainless Steel... High Strength, Permanent Beauty, Maximum Corrosion Resistance ... Easy to Clean and Keep Clean.

Superior Steel
CORPORATION
CARNEGIE · PENNSYLVANIA

New Descriptive Bulletin Available on Request

ANOTHER WILCO DEVELOPMENT



Wilcoloy

(SINTERED POWDER METAL CONTACTS)

WILCOLOY *offers* Longer Contact Life . . . Greater Resistance to Interrupting Loads, *and many other advantages for high current applications.*

PROPERTIES AND CHARACTERISTICS—WILCOLOY Silver Tungsten, Copper Tungsten, Silver Graphite, Silver Molybdenum and other WILCOLOY contact materials assure a degree of longevity, and thermal and electrical properties not possible to materials previously used in applications subject to severe current interruptions.

These Sintered Powder Metal Contacts offer a choice of properties including ductility, hardness, density, freedom from sticking, low metal transfer, high conductivity and arc-resistance. They perform uniformly and dependably in heavy duty circuit breakers, both air and oil relays, aircraft units, motor brushes, commutator segments, fuse replacement units and other specialized applications.

CONSULT OUR ENGINEERING DEPARTMENT—Write our Engineering Department for help in developing the proper application of WILCO materials to your products.

SEND FOR WILCO BLUE BOOK—The Blue Book contains descriptions of most WILCOLOY Sintered Powder Metal Contacts and other WILCO products. Send for FREE copy today.

WILCO PRODUCTS INCLUDE:

CONTACTS—
Silver
Platinum
Tungsten
Alloys
Sintered Powder Metal

THERMOSTATIC BIMETAL—
All Temperature ranges, deflection rates and electrical resistivities.

PRECIOUS METAL COLLECTOR RINGS—
For rotating controls

SILVER CLAD STEEL—

JACKETED WIRE—
Silver on Steel, Copper, Invar or other combinations requested.

ROLLED GOLD PLATE

SPECIAL MATERIALS

THE H. A. WILSON COMPANY
105 Chestnut Street, Newark 5, N. J.
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SPECIALISTS FOR 30 YEARS IN THE MANUFACTURE OF THERMOMETALS ELECTRICAL CONTACTS • PRECIOUS METAL BIMETALLIC PRODUCTS

Streamlined for Action!

Fire engines of the future, so designers tell us, will be ultra-modern in design and efficiency, incorporating many new features. Aluminum and magnesium will play a vital part in many of the post-war designs now on drawing boards throughout America. Their use eliminates weight—reduces operating costs—and adds greatly to eye and sales appeal. If your product now uses—or can use—these versatile light alloys, the Bohn Engineering staff would like to discuss with you their many outstanding advantages.

BOHN ALUMINUM AND BRASS CORPORATION
GENERAL OFFICES—LAFAYETTE BUILDING • DETROIT 26, MICHIGAN
Designers and Fabricators
ALUMINUM • MAGNESIUM • BRASS • AIRCRAFT-TYPE BEARINGS

BOHN

Specify MO-MAX for SUPERIOR PERFORMANCE

YOU CAN expect better results from tools made of this pioneer molybdenum-tungsten high speed steel. MO-MAX has clearly demonstrated its superior qualities in drills, reamers, lathe tools, cut-off tools, tool bits, milling cutters, hobs, circular saws, thread rolling dies, counterbores, broaches, lathe centers, spot facers, circular and flat forming tools, dies for both hot and cold work, taps, thread chasers, etc.

MO-MAX

MOLYBDENUM-TUNGSTEN HIGH SPEED STEEL

is available from the mills listed below. Each brand name represents a steel that is made according to a genuine MO-MAX formula.

ALLEGHENY LUDLUM STEEL CORP. . . "LMW"	HALCOMB STEEL COMPANY . . . . . "REX T-MO"
ATLAS STEELS, LIMITED . . . . . "MOHICAN"	JESSOP STEEL COMPANY . . . . . "MOGUL"
BETHLEHEM STEEL COMPANY . . . . . "BETHLEHEM HM"	LATROBE ELECTRIC STEEL COMPANY . . . . "TATMO"
BRAEBURN ALLOY STEEL CORPORATION . "MO-CUT"	ST. LAWRENCE ALLOYS, INC. . . . .
CARPENTER STEEL COMPANY . . . . . "STAR MAX"	SIMONDS SAW & STEEL COMPANY . . . . . "S.T.M."
COLUMBIA TOOL STEEL COMPANY . . "MOLITE M-1"	UNIVERSAL-CYCLOPS STEEL CORP. . . . . "MO-TUNG"
CRUCIBLE STEEL CO. OF AMERICA . . "REX T-MO"	VANADIUM-ALLOYS STEEL COMPANY . . . "8-N-2"
HENRY DISSTON & SONS, INC. . . . . "DI-MOL"	VULCAN CRUCIBLE STEEL COMPANY . . . . "VUL-MO"
FIRTH-STERLING STEEL COMPANY . . . "HI-MO"	

FOR THE FULL STORY ON MO-MAX high speed steels—their physical properties, their advantages, and how to heat treat them—write today for the new, revised MO-MAX Handbook.

★ ★ ★

THE CLEVELAND TWIST DRILL COMPANY • 1242 East 49th Street • Cleveland 14, Ohio

New SPEED QUENCH FURNACE

Ask for complete information now

The Upton Speed-Quench Furnace supplies the two essentials for quenching:

- Rapid heat dissipation.
- Vigorous agitation of molten salt.

The Upton Speed-Quench Furnace is built with a series of step-backs. The resulting surface area allows heat radiation at a rate far in excess of the rate that heat is brought into the bath by the work.

To provide a balance of heat and thus keep the heat at the proper quenching temperature, electrodes put additional heat into the furnace at the bottom of the pot. The amount of heat to be added is relatively high because of the exceptionally high rate of heat dissipation. The result:

A vigorous, continuous surge of molten salt throughout the entire bath.

Work that is quenched by this flow comes out of the bath uniform and without quench defects.

We can build Upton Furnaces to heat-treat *your* work.

Upton ELECTRIC FURNACE DIV.

7435 MELVILLE AT GREEN • DETROIT 17, MICHIGAN

OUT OF THE Past

BETTER MADE STEELS
LABORATORY TESTED
SINCE 1891

COMES Prestige

ULTRA-CUT STEEL

Prepare for increased production and profits by standardizing on ULTRA-CUT Bessemer Screw Stock. Its amazing production record on high-speed automatics makes it the all-time choice of industry. Use this *economy screw stock* for fabricating quality machine parts . . . and win new prestige for your products.

BLISS & LAUGHLIN, INC.

HARVEY, ILL. • BUFFALO, N. Y. • MANSFIELD, MASS.

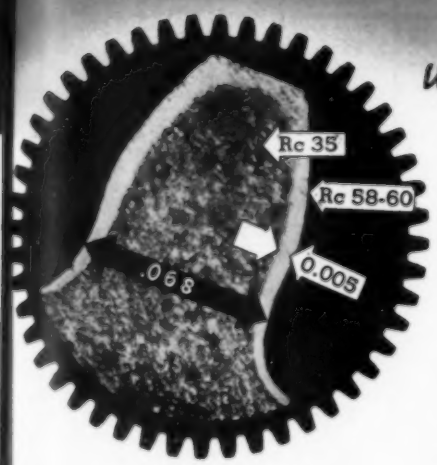
Sales Offices in all Principal Cities

COLD FINISHED STEEL AND SHAFTING

They're All Talking About It!

A New Thin Case Contour Hardening Job . . .

with MEGATHERM*



Thin case contour hardening of gear teeth with controlled depth of hardness has been made possible by the use of MEGATHERM induction heat.

The hardened surface completely follows the tooth and root contour of the gear with the core still in its original state, as shown plainly by this microphotograph. This 0.005 case was applied to gears of 24 D. P. —51 teeth—2.125 P. D.—2.208 O. D. and S.A.E. 4140 steel in 1/4 of 1 second with a 25 KW MEGATHERM—5 megacycle energy doing the job.

These long wearing contour hardened gears become an automatic production item with MEGATHERM.

Write *today* on your company letterhead for data on MEGATHERM.

Federal Telephone and Radio Corporation

AN IT&T ASSOCIATE

Newark 1, N. J.

*REG. U. S. PAT. OFF.

TOOL STEEL DATA

Revised Data for Water Hardening Tool Steels including types, analyses, uses, hardening characteristics and temperature ranges

DECEMBER, 1945

WATER HARDENING TOOL STEEL CHARACTERISTICS

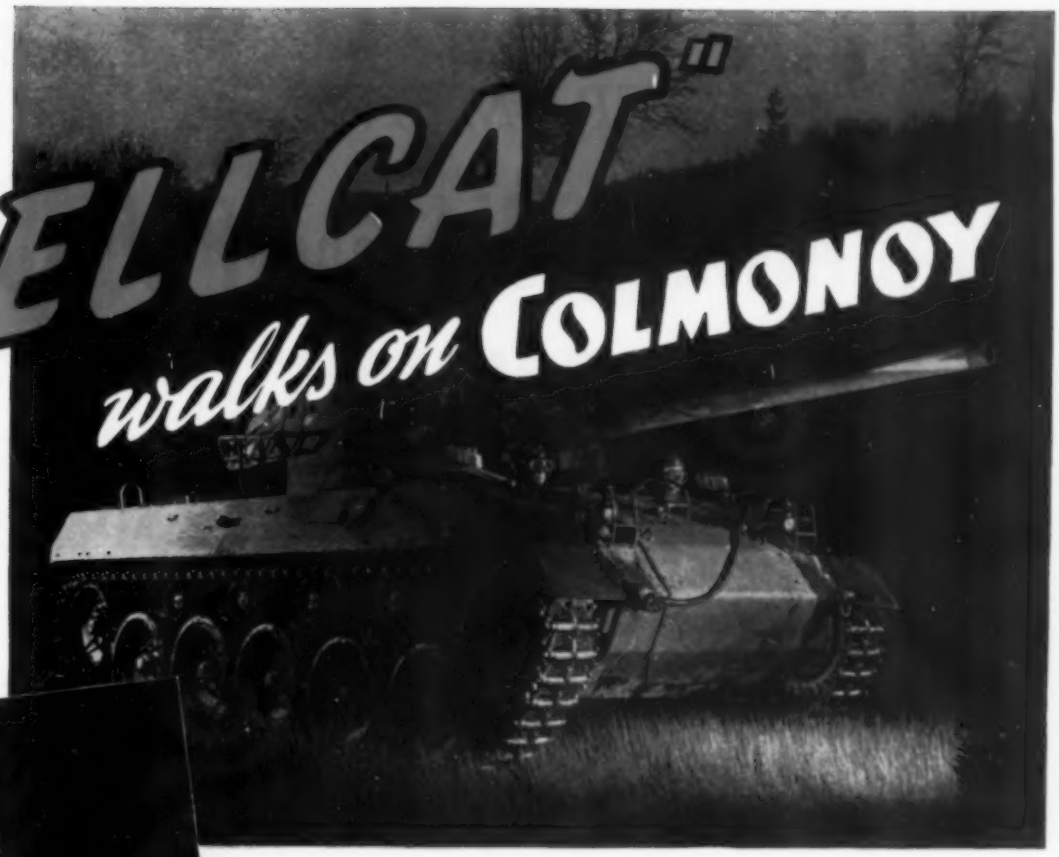
TYPE	GRADE	ANALYSIS	USES Water Hardening Tool Steel for Cold Work Dies and Tools Requiring:	HARDENING CHARACTERISTICS		
				HARDENING TEMPERATURES	QUENCH	RC
Carbon Alloy Treated	SPECIAL	C * Mn .25 Si .25 Cr .15 V .04	• Highest Quality • Keen Cutting • High Surface Hardness with a Tough Core	Range: 1420° F. to 1530° F. Cutting and Shearing Tools: 1420° F. to 1450° F. Parts Subject to Steady Pressure: 1440° F. to 1480° F. Dies Subject to Severe Blows: 1470° F. to 1530° F.	Water or Brine	64-66
Carbon	EXTRA	C * Mn .25 Si .20	• High Hardness of Medium Depth • Good Wear Resistance • Shock Resistance	Range: 1425° F. to 1550° F. Cutting and Shearing Tools: 1425° F. to 1450° F. Forming; Steady Pressure Tools: 1440° F. to 1490° F. Dies Subject to Heavy Blows: 1500° F. to 1550° F.	Water or Brine	64-66
Carbon Vanadium	VANADIUM EXTRA	C .95 Mn .30 Si .25 V .20	• Increased Wear Resistance • Added Toughness and Fatigue Resistance	Range: 1450° F. to 1500° F.	Water or Brine	64-66
Carbon Chrome	WATERDIE	C 1.00 Mn .35 Si .25 Cr. .55	• Uniform Strong Case in Large Sections • High Wear Resistance	Range: 1500° F. to 1525° F.	Water or Brine	64-66
Carbon Manganese	EXTRA HEADER DIE	C .95 Mn .35 Si .25	• Uniform Deep Hardening in tools such as Header Dies	Range: 1475° F. to 1550° F.	Water or Brine	64-66
QUENCHING: A brine quench 60° to 80° F. is recommended. Remove tools from the quench at approximately 300° F. and cool in air to about 125° F. and temper immediately.						
TEMPERING: These are usually tempered from 300° F. to 600° F. As the temperature increases, hardness decreases and toughness increases.						
NOTE: These steels meet rigid Hot Etch and Hardenability Standards. Water hardening steels harden with a depth of case of ⅛" to ¼" depending on Mass, Hardening Temperature and Hardenability. *Available in 3 carbon ranges: approx. C 1.15; approx. C 1.05; and approx. C .95.						

COLUMBIA TOOL STEEL COMPANY

MAIN OFFICE AND WORKS—CHICAGO HEIGHTS, ILLINOIS

Branches and Warehouses . . . CHICAGO • CINCINNATI • CLEVELAND • DETROIT • MILWAUKEE

The "HELLCAT" walks on COLMONOY



Colmonoy Sweat-on Paste is applied at three points on the track links. The Hellcat "walks on Colmonoy".

Colmonoy is combined with the parent metal of the links by electric arc-welding.

● The "Hellcat" is a tank destroyer of exceptional maneuverability. It has a speed of up to 55 miles an hour, and carries a 76-millimeter gun of high velocity and destructive fire power. The "Hellcat" was designed and manufactured by Buick Motor Division of General Motors Corporation.

The carbon steel forged track was one reason for the tremendous success of this weapon in the European theater of operations. Track design, a new type of suspension and long service life made this track outstanding.

And about six square inches of Colmonoy per link, from 1/16" to 1/8" thick, was a big factor in the long life of the track.

There are three deposits of Colmonoy on each link. Colmonoy Sweat-On Paste is applied with a putty knife, through openings in a template, and arc-welded. The fused layer of Colmonoy hard-facing extends about 1/8" into the forging, and has a hardness of 65 Rockwell C, providing increased resistance to impact and abrasion, making each link practically wear-proof.

Colmonoy Hard-Facing Alloys are available in many grades. Our catalog gives full information. Write for it.

WALL COLMONOY
Corporation
720 FISHER BLDG., DETROIT 2, MICH.

GOVERNMENT SURPLUS

MACHINE TOOLS and PRODUCTION EQUIPMENT

CAN HELP YOU RECONVERT!

Government-owned Machine Tools and Industrial Equipment are available now to help industry shoulder the reconversion load.

It is the responsibility of the Reconstruction Finance Corporation to dispose of these surpluses as soon as possible—to turn them over to private industry, where they'll do the greatest good for the most people in the shortest time.

Therefore, in order to speed reconversion by getting this equipment into the hands of skilled craftsmen, faster . . . we ask you to follow this simple procedure:

1. **Submit in writing your requirements for machine tools and industrial equipment to us *now*.**
2. **Send a typewritten list to your nearest R.F.C. Regional Office listed below.**
3. **Make your descriptions brief, one line if possible, clearly grouping various types of equipment you need.**

The supply of surplus tools is sufficient to meet all of the needs of industry, and in the event that your local R.F.C. Regional Office cannot fill your specific requirements, it will endeavor to locate needed equipment from other offices throughout the country.

First step in creating jobs is getting machines in motion faster.

The 31 strategically located agencies below are ready to make your reconversion problems easier.

RECONSTRUCTION FINANCE CORPORATION

A DISPOSAL AGENCY DESIGNATED BY THE SURPLUS PROPERTY ADMINISTRATION

Agencies located at: Atlanta • Birmingham • Boston • Charlotte • Chicago • Cleveland • Dallas • Denver Detroit • Helena • Houston • Jacksonville • Kansas City, Mo. • Little Rock • Los Angeles • Louisville Minneapolis • Nashville • New Orleans • New York • Oklahoma City • Omaha • Philadelphia Portland, Ore. • Richmond • St. Louis • Salt Lake City • San Antonio • San Francisco • Seattle • Spokane

NOW!

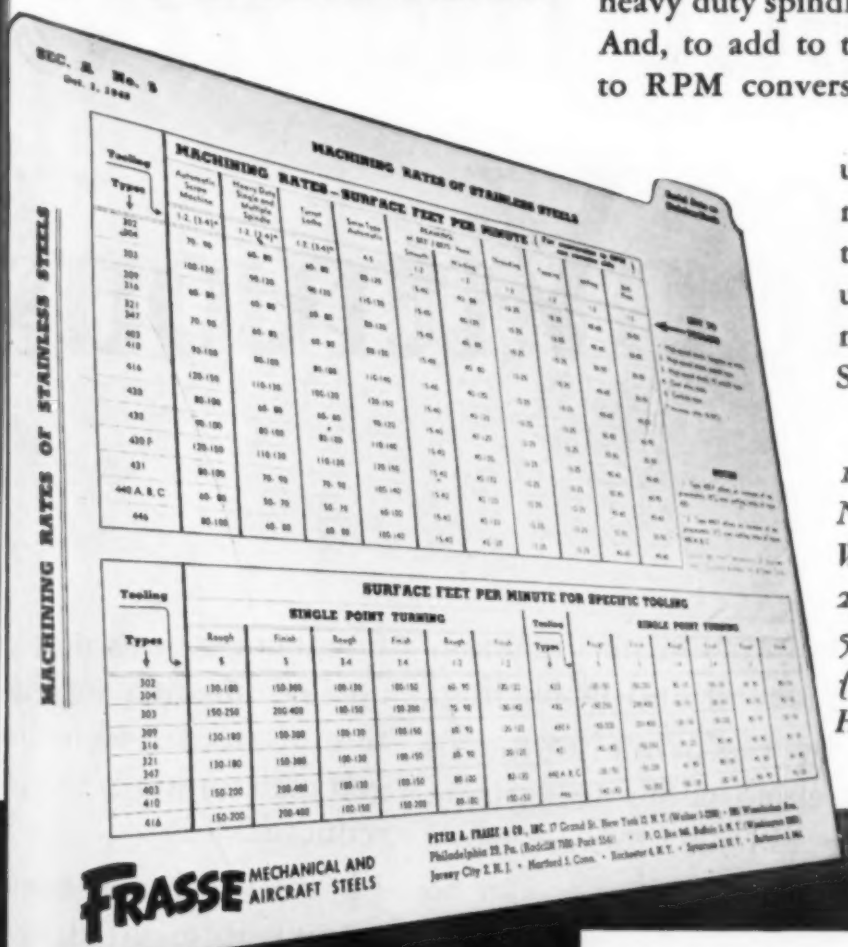
"STAINLESS" MACHINING RATES AT YOUR FINGERTIPS

Here's another Frasse help for stainless steel users: a table of recommended machining rates for 18 stainless types... for 10 separate operations... with specific tooling data — all condensed in one easy-to-use, quick reference chart!

This new Frasse chart shows for *each stainless grade*, recommended rates for turning, threading, milling, tapping and drilling...with high-speed, cast alloy or carbide type toolings. Turning rates are detailed to cover automatic, heavy duty spindle, turret and Swiss-type lathes. And, to add to the chart's usefulness, a SFM to RPM conversion table is included.

If you use or contemplate using stainless, you'll find this new chart...like Frasse inventories and technical counsel... unusually helpful in your planning, production or purchasing. Send for your free copy today.

Peter A. Frasse and Co., Inc., 17 Grand Street, New York 13, N. Y. {Walker 5-2200} • 3911 Wissahickon Ave., Philadelphia 29, Pa. {Radcliff 7100-Park 5541} 50 Exchange St., Buffalo 3, N.Y. {Washington 2000} • Jersey City, Hartford, Rochester, Syracuse, Baltimore.


SEC. A, No. 5
Oct. 1, 1945

MACHINING RATES OF STAINLESS STEELS

MACHINING RATES—SURFACE FEET PER MINUTE

SURFACE FEET PER MINUTE FOR SPECIFIC TOOLING

SINGLE POINT TURNING

PETER A. FRASSE & CO., INC. (17 Grand St., New York 13, N. Y. (Walker 5-2200) • 3911 Wissahickon Ave., Philadelphia 29, Pa. (Radcliff 7100-Park 5541) • P. O. Box 946, Buffalo 5, N. Y. (Washington 2000) • Jersey City 2, N. J. • Hartford 5, Conn. • Rochester 4, N. Y. • Syracuse 2, N. Y. • Baltimore 3, Md.

FRASSE MECHANICAL AND AIRCRAFT STEELS

FRASSE

MECHANICAL AND AIRCRAFT STEELS

Alloy, Stainless, and Cold Finished Carbon Steels
Bars, Sheets, Tube, Strip and Wire

Peter A. Frasse & Co., Inc. 71-K
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Please send me, without obligation, a copy of your new data chart Sec. A, No. 5—'Machining Rates of Stainless Steels'

Name .....

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Are you informed about the *new* for Vitreous

LABORATORY-TESTED and plant-proved are the advantages of this *new* Titanium steel to manufacturers of vitreous enamel products, when recommended practice is followed in steel making, pickling and enameling.

By removing source of reboil in the stock, large cost reductions are possible. Ground coat can be eliminated and conventional cover coats may be applied directly. Sagging is minimized, and hydrogen penetration is sharply reduced.

Lighter weights of enamel are possible, yielding a

THE TITANIUM ALLOY

Metal Progress; Page 1262

Titanium Steel Enameling?

greater resistance to thermal shock. Drawing properties are equivalent to that of the best drawing steel.

Manufacturers of both steel and enameled products may obtain complete technical data from a member of our Technical Staff. Consult your steel supplier for deliveries.

★ ★ ★

Pending patent applications on the new enameling process and product made thereby are owned jointly by Inland Steel Company and The Titanium Alloy Manufacturing Company under Trust Agreement.

Executive Offices:
111 Broadway, New York, N. Y.

General Offices and Works:
Niagara Falls, N. Y.

MANUFACTURING COMPANY

DEFECTS DON'T GET UNDER their SKIN!

These bronze parts, a stern tube bushing assembly, typical of thousands of precision tubular parts produced for the Government's war needs, as well as for the textile industry, were cast centrifugally and then finished in Shenango-Penn's own modern machine shops.

IN finishing large rolls and other important precision parts for engines, machinery or drives, it's costly business to spend man and machine hours only to turn up hidden defects in metallic structure. And, often enough, it's even more costly when such defects *stay* hidden until trouble develops in service.

The best way to lessen such risks, to lower your ultimate cost, is to specify Shenango-Penn centrifugal castings for all tubular or circular parts. You'll find them free from porosity, blowholes, sand inclusions or other structural weaknesses. They have greater density and higher tensile strength than other castings of the same analysis.

Shenango-Penn will supply rough castings or, if you prefer, deliver finished parts expertly machined to close tolerances in our own modern, completely equipped machine shops. In either case you gain lower production costs and a more dependable, more durable product.

Write for bulletin 143 which gives complete information about Shenango-Penn centrifugal castings, including chemical and physical analyses and specifications of various alloys available.

Free bulletin 143 is yours for the asking.

SHENANGO-PENN MOLD COMPANY
1659 WEST THIRD STREET • DOVER, OHIO
Executive Offices: Pittsburgh, Pa.

SHENANGO-PENN

ARMY NAVY

ALL BRONZES • MONEL METAL • ALLOY IRONS

What new "armor" for steel can save America millions each year?

YEAR AFTER YEAR—in war or peace—America pays a colossal toll in dollars to a foe as unrelenting as any ever known.

It is the enemy *rust*, that attacks and destroys things made of steel. But now a remarkable new discovery can bring you steel products that will *defy* rust up to 4 times longer . . . Hardware, screens, fencing, automobiles, tractors, dozens of important items that will outlast any you've ever owned by as much as 4 to 1!

This remarkable discovery is CORRONIZING, the patented alloy "armor" that gives steel a new lease on life. Yes, CORRONIZING is new . . . but also thoroughly tested and proved. For CORRONIZING has demonstrated its overwhelming superiority in the war, under the worst possible conditions on land, at sea and in the air.

By test and performance, CORRONIZING FAR OUTLASTS OTHER PROTECTIVE COATINGS FOR STEEL. Now, the more progressive factories and retailers will be able to bring you products made of "Corronized" steel. Motor car makers—always leaders—will be among the first to offer you this sensational advantage.

Remember that name—CORRONIZING. It can save you and millions of other Americans a huge tax bill now needlessly paid to the enemy rust.

Standard Steel Spring Co.

ORIGINATORS OF

CORRONIZING

The Magic Carpet to Longer Life for Steel

Quick Facts for Manufacturing and Sales Executives

Do not confuse CORRONIZING with other metal coatings. This patented process provides a permanent alloy "armor" with 5 layers of defense against corrosion! It becomes part of the steel base . . . can be worked in any manner. Permits using lighter materials by prolonging steel's period of greatest strength. Write for samples and complete information.

STANDARD STEEL SPRING COMPANY
CORAOPOLIS, PENNSYLVANIA

Painting by Doris Zinkeisen

This Present Age . . 7

It is no new thought that security and freedom from want in old age should be the concern of established industry. As long ago as 1882 the Samuel Fox Stocksbridge Benefit Fund was founded to provide for retired employees. This fund continues to-day as do provisions at other branches. With time it became desirable to adopt more liberal policies. In 1935 and 1936 four voluntary contributory pension schemes were launched to cover the administrative and office staffs, establishment personnel, foremen and all other workers. They formed the largest comprehensive project of its kind ever established, and, so far, the only one within the industry incorporating all the workpeople. The schemes are generous in their scope and impose a heavy annual liability on the company, to which is now added the responsibility for the contributions of its 5,072 employees serving in H.M. Forces. These insurances are an instance of the initiative of enlightened management in social reform, and are tangible proof that this organisation has a sincere and profound appreciation of human needs and aspirations. The community depends on steel to satisfy its necessities and provide its amenities. Thus it is of national interest that the development and economic stability of the industry should provide steady employment and social security for the company's employees.

THE UNITED STEEL COMPANIES LTD

THE UNITED STEEL COMPANIES LIMITED

17, WESTBOURNE ROAD . SHEFFIELD 10

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SAMUEL FOX & CO. LTD., SHEFFIELD
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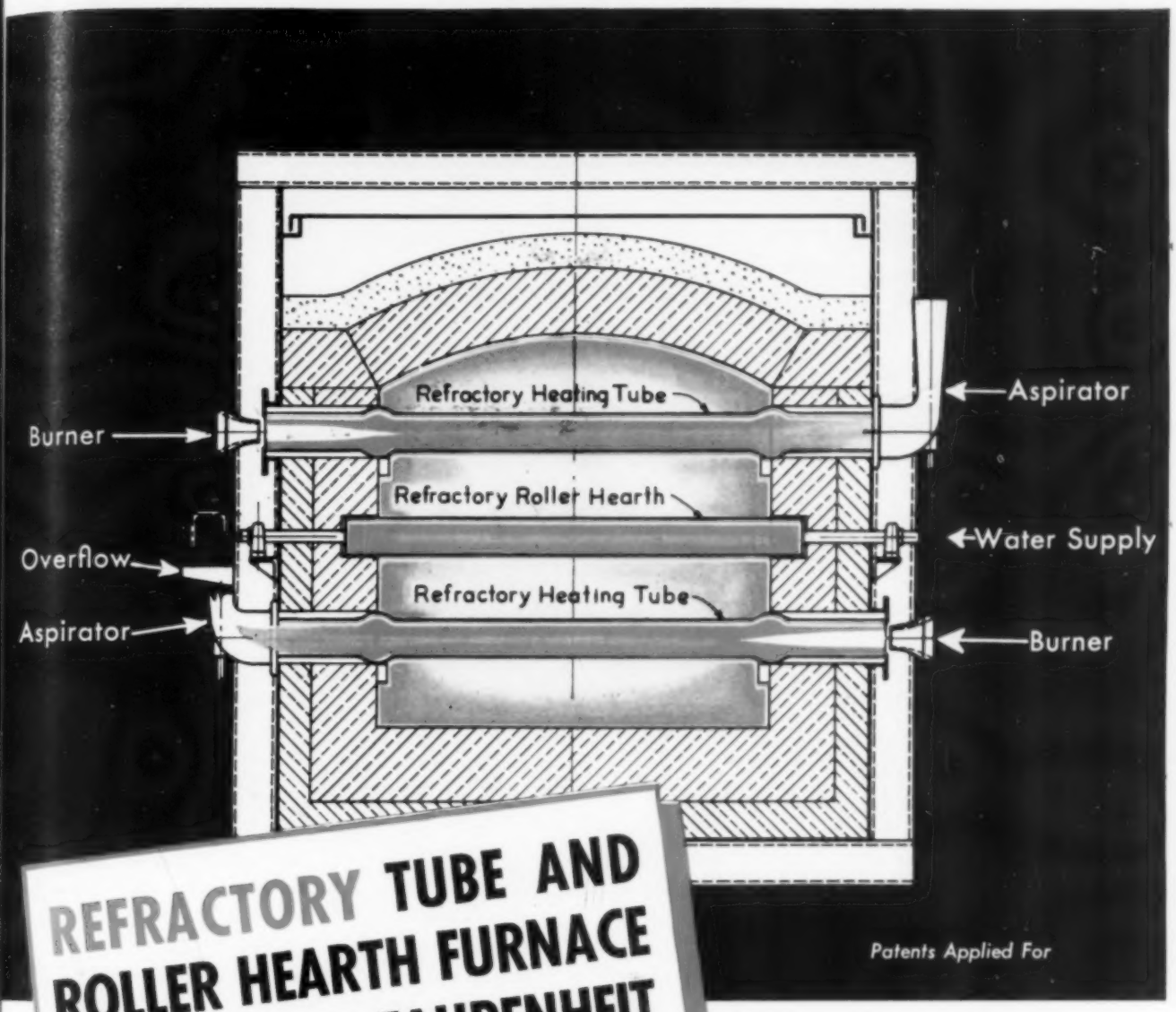
U.S.P. 39



REFRACTORY TUBE AND ROLLER HEARTH FURNACE UP TO 2500° FAHRENHEIT

Patents Applied For

Creative heat engineering has developed a refractory burner tube and furnace roller hearth that promise increased furnace efficiency, higher temperatures and reduced maintenance.

RADIANT BURNER TUBES

The perfection of gas-tight tubes, patents applied for, of high temperature refractory, now provides an improved luminous flame burner tube.

In the view above, with burners at either end of the tubes, the furnace is provided with all the advantages which would be expected from a good high temperature refractory, such as resistance to spalling, chemical inertness, and long life. Such refractory burner tubes are advantageous in heating the work apart from products of combustion in controlled atmospheres to temperatures as high as 2500° F.

SILICON CARBIDE ROLLERS

The refractory roller, patents applied for, stands high temperatures, provides extended life and service, and reduces heat loss to a practical minimum with an increase in furnace capacity by withstanding increased hearth loads.

The Refractory Roller consists essentially of a tube of silicon carbide supported concentrically upon a hollow steel shaft by high temperature insulating refractory. Sizes are engineered to load and temperatures up to 2500° F. The hollow steel shaft is water cooled. In a seven months' test in a furnace annealing stainless steel, the rollers gave continuous service and were in as good condition as when installed.

FACTS AVAILABLE

Complete facts on these radiant burner tubes and rollers and engineering information on standard and special furnaces equipped with these new developments will be furnished promptly. The engineering staff of this company has an experienced background in the efficient use of gas heat and is at your service today to work with you on your heating problems.

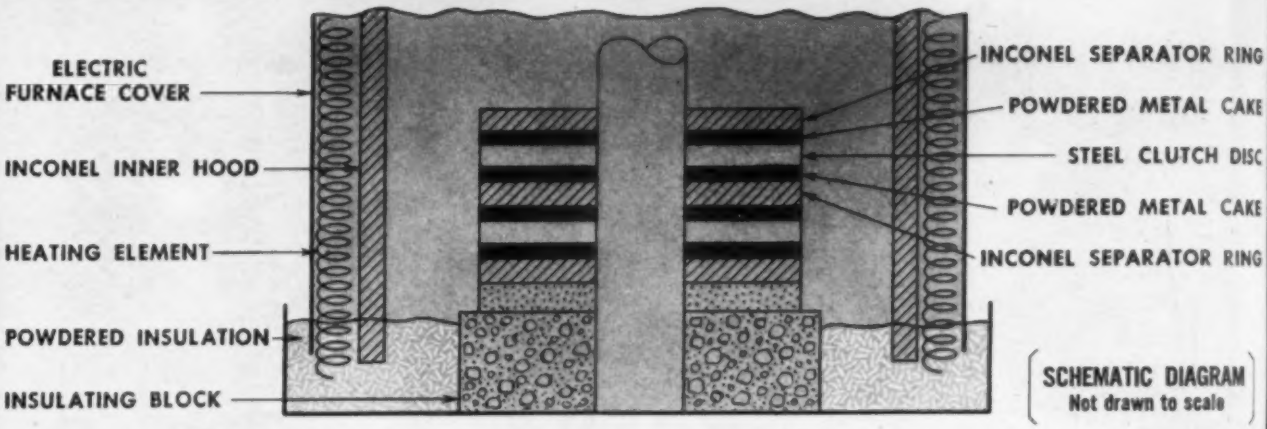
Write or wire for complete information.

GAS MACHINERY
Company
16100 WATERLOO ROAD
CLEVELAND 10, OHIO

THE JOB —
Bonding powdered metal to steel at 1400° to 1900°F.

THE PROBLEM —
Keeping surfaces uniform

THE SOLUTION —
Inconel separator rings



At the S. K. Wellman Company, powdered metal facings are bonded to steel clutch discs and steel brakes.

In this operation, packs of powdered metal cakes and their steel bases are kept separated by metal rings. Such rings:

. . . must not warp or expand excessively at 1400°-1900° F., if the powdered metal surfaces are to remain undistorted

. . . must not adhere to the powdered metal surface, but make a clean separation between each pack

. . . must remain unaffected by the gases generated during the bonding process

. . . must cause no contamination of the powdered metal surface due to scaling, corroding or oxidizing

Steel separator rings were tried first. But they warped so badly that frequent replacements were necessary. Moreover, to prevent sticking, they had to be coated with graphite six times a day.

Excessive warping and sticking also resulted when various types of heat-resisting alloys were used.

Finally, Inconel separator rings were tried.

That ended the problem!

Inconel rings are easily stamped from sheet. They require a graphite coating *only once every three weeks.*

With Inconel rings, no distortion harms the sintered surface. Separation is clean. And, equally important, the Inconel rings remain true and usable over and over without replacement.

The great thermal endurance of Inconel also makes it the choice for the inner hood between the heating elements and the charge.

The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

NICKEL INCO TRADE MARK **ALLOYS**

MONEL* • "K" MONEL* • "S" MONEL* • "R" MONEL* • "KR" MONEL* • INCONEL* • NICKEL • "L" NICKEL* • "Z" NICKEL*

Sheet...Strip...Rod...Tubing...Wire...Castings...Welding Rods (Gas & Electric)

Reg. U. S. Pat. Off.

IT TAKES ALL 3

– for complete Tool and Die Steel Service

1

Outstanding Mill Quality

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Strategically Located Warehouses { DETROIT, CHICAGO, TOLEDO
CLEVELAND, PHILADELPHIA
LATROBE, HARTFORD

3

Dependable Metallurgical Service { Latrobe service men are always glad to render personal counsel on your particular problems.

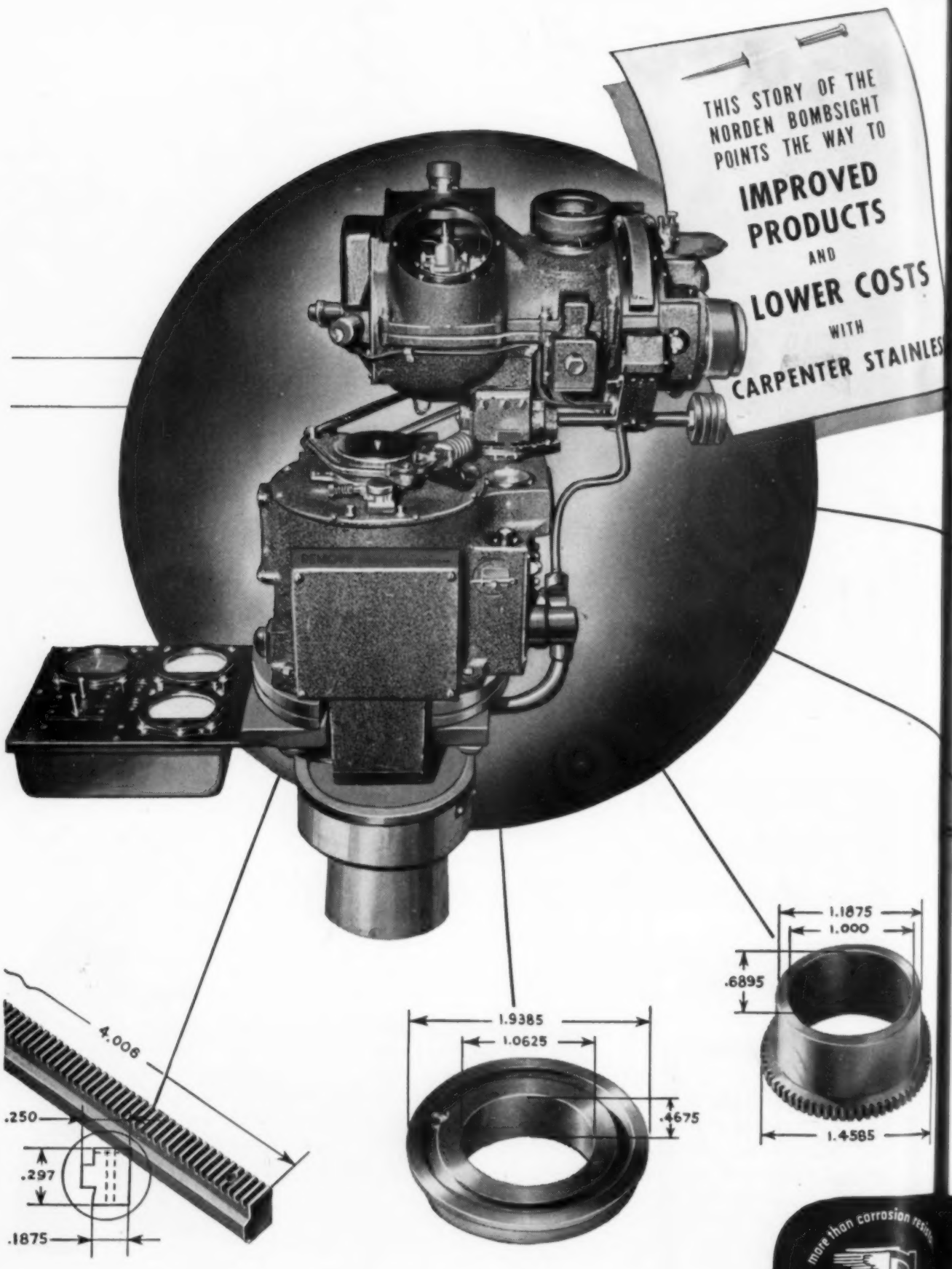
LATROBE

LESCO

- **High Speed Steels**
- **Die Steels**
- **Tool Steels**
- **Stainless**
- **Red Arrow**
  Cast Alloy for Metal-Cutting Tools.
  Welding Rod for Hard Facing.

Latrobe **ELECTRIC STEEL COMPANY**

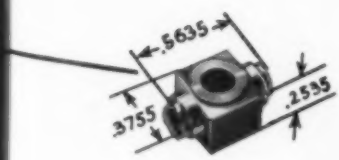
S-6 MAIN OFFICES *and* PLANT •• LATROBE • PENNSYLVANIA

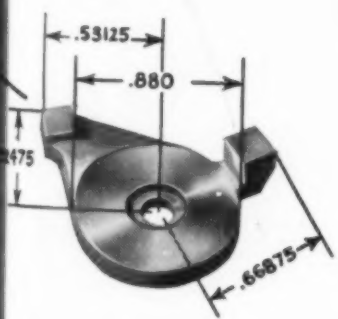


THE CARPENTER STEEL COMPANY, 133 W. Bern Street, Reading, Pa.

To Get *High Precision* Parts with *Fewer Rejects*

. . . use the Stainless that met exacting Norden bombsight requirements





● If ever a job called for close tolerances, plus product dependability, it was this famous bombsight.

The requirements were tough. For instance, one small piece —the heart and nerve center of the bombsight—was held to a tolerance of ±.0001". The part contained less than 1¢ worth of steel, yet was listed as an $8 cost item. Stainless was a "must" for this and many other vital parts, because corrosion resistance, wear resistance and a high strength/weight ratio were necessary.

Why Carpenter Free-Machining Stainless was first choice for these bombsight parts is a story that can now be told.

You can sum it up in one word—"dependability". Said one of the factory superintendents: "Experience with material obtained from other sources has convinced me that we have *less rejections, better machining time, less trouble* in straightening, and *better tool life* with Carpenter Stainless No. 5 bar stock."

Your own precision requirements may be less severe, but you will benefit by the consistent, money-saving uniformity of Carpenter Free-Machining Stainless. Made to tool steel standards in a tool steel mill, Carpenter Stainless guarantees top-flight performance.

Try Carpenter Free-Machining Stainless Steels and see what a difference they make in your production set-up. Your nearby Carpenter representative will gladly help you in solving your Stainless problems. Call him or write us at the mill.

Carpenter STAINLESS STEELS

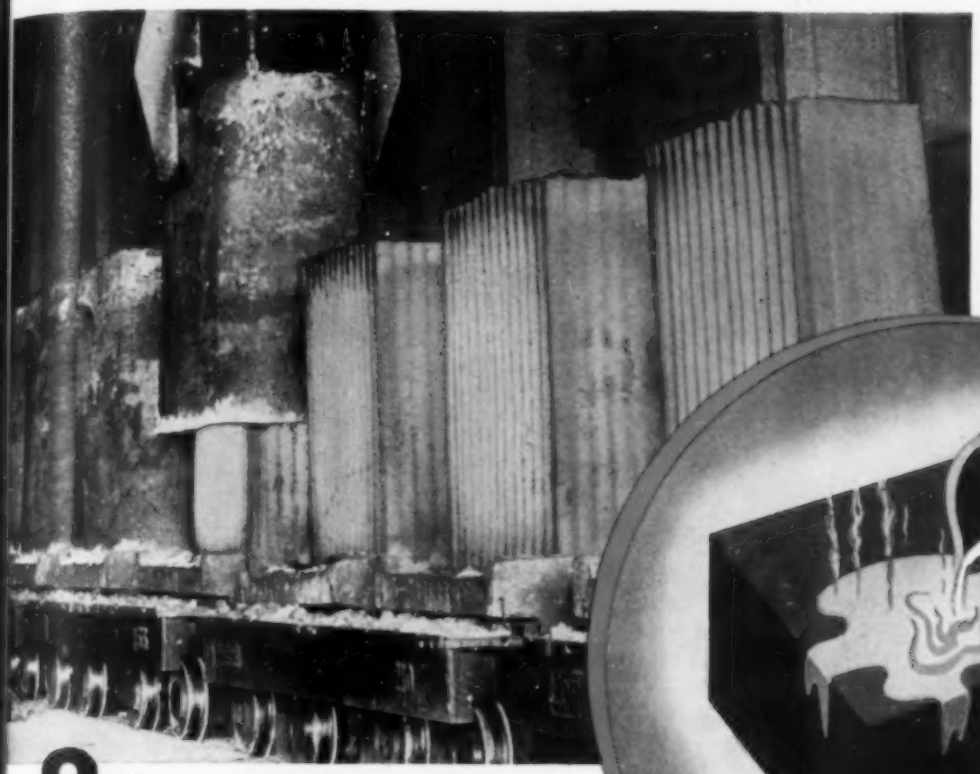
BRANCHES AT Chicago, Cincinnati, Cleveland, Detroit, Hartford, Indianapolis, New York, Philadelphia, Providence, St. Louis

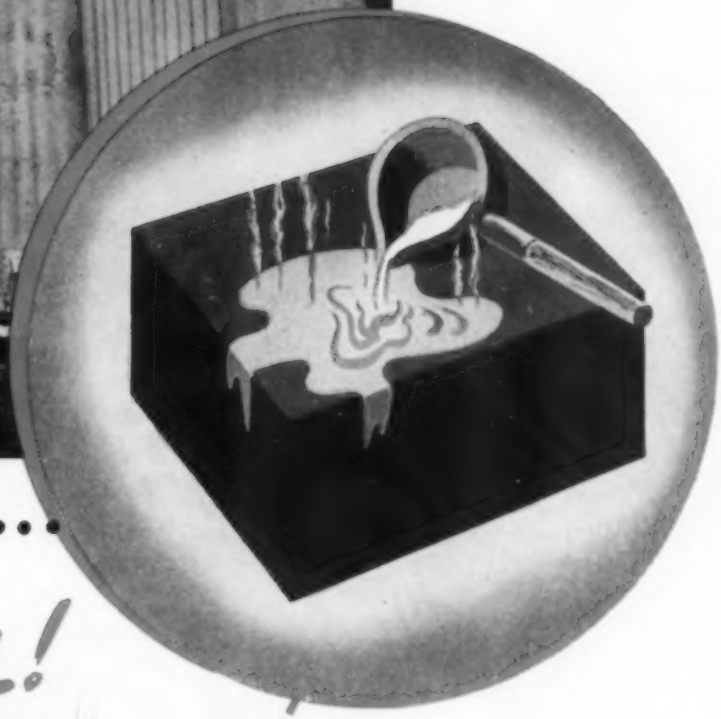
J&L STEEL

Our metallurgical engineers will be glad to discuss your production problems with you.

JONES & LAUGHLIN
STEEL CORPORATION
PITTSBURGH 30, PENNSYLVANIA

SPECIAL COLD DRAWN SHAPES SAVE MACHINING





8th ADVANTAGE...

NOT WET BY MOLTEN METAL!

IMAGINE!—1500 steel ingots on graphite stool inserts in one plant—*without any stickers!* That's because molten metals simply do not stick to carbon or graphite!

This eighth advantage of "National" carbon or graphite is only one of many responsible for the adoption of these materials by the metal-working industries, in the form of stool inserts, mold plugs, molds, mold wash (graphite powder), run-out troughs, and furnace linings. Another advantageous feature in run-out troughs and furnace linings: the carbon blocks are unaffected by the most corrosive slags.*

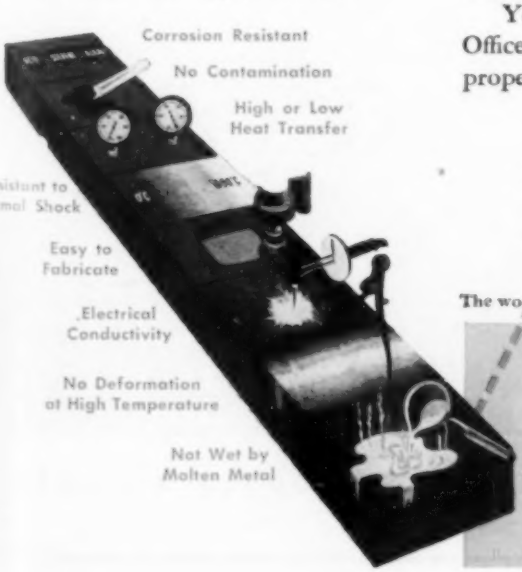
You are invited to get the full story . . . from our nearest Division Office . . . on carbon's, or graphite's, truly remarkable *combination* of properties, whether in the ordinary, porous, or impervious forms.

***Chemical Engineers Please Note**

Of parallel importance to the chemical industries are other advantages of "National" carbon and graphite and "Karbate" impervious materials. They are resistant to the corrosive action of most acids, alkalies, and solvents, and they do not contaminate solutions.

BAR OF WHAT?

Carbon, Graphite, or "Karbate" materials, of course!



The words "National" and "Karbate" are registered trade-marks of National Carbon Company, Inc.

NATIONAL CARBON COMPANY, INC.

Unit of Union Carbide and Carbon Corporation

UCC

General Offices: 30 East 42nd Street, New York 17, N. Y.

Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

MEET THE NEW CHAMPION

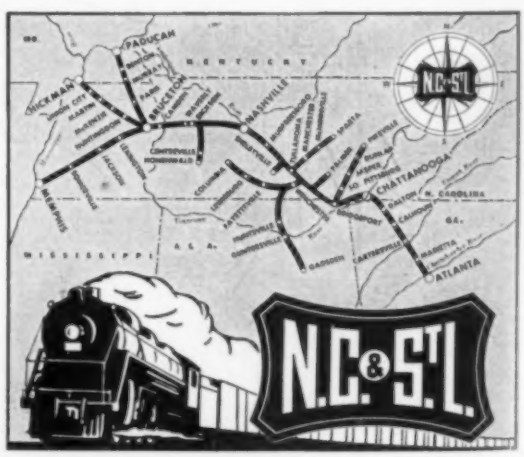
Fighting its way upward, the South's dollar income has not only *doubled* in the past few years but it has increased proportionately more than the income for the country as a whole!

For those who manufacture and sell, this fact alone spells opportunity. It means greater purchasing power . . . a ready market for more and better merchandise of every description.

But this is only one of many factors that account for the astounding progress of the Southern region. Long a contender for top-flight honors, World War II kindled the vital spark that has, according to Dr. Wilfred White, of the Bureau of Foreign & Domestic Commerce, "Stepped up the South's management know-how, skills, plants and equipment." The South is, he adds, "*a number one frontier.*"

With its unexcelled advantages of abundant raw materials and intelligent, native-born workers . . . its low-cost electric power and adequate transportation facilities, *the South has everything! That's why wise industrialists are choosing the South.*

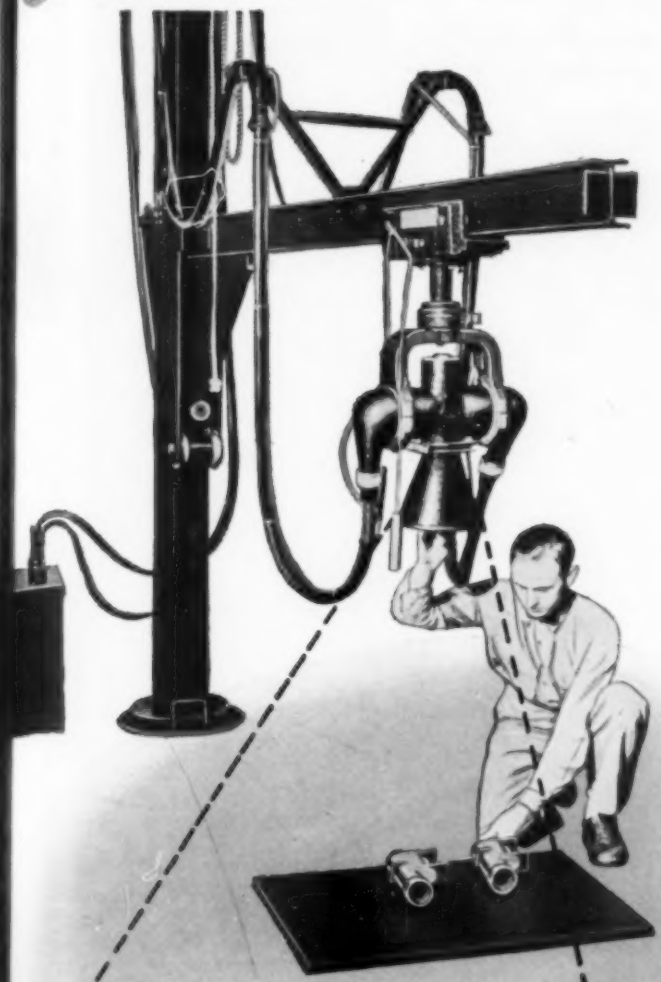
If your objective is lower manufacturing and distribution costs — increased volume — and consequently greater profits — it will pay you to take a close look at N. C. & St. L. territory . . . Land of Industrial Opportunity. For details, consult: J. A. Senter, General Development Agent, N. C. & St. L. Railway, Nashville 3, Tennessee.



THE NASHVILLE, CHATTANOOGA & ST. LOUIS RAILWAY

BUY AND KEEP VICTORY BONDS

Control Radiography

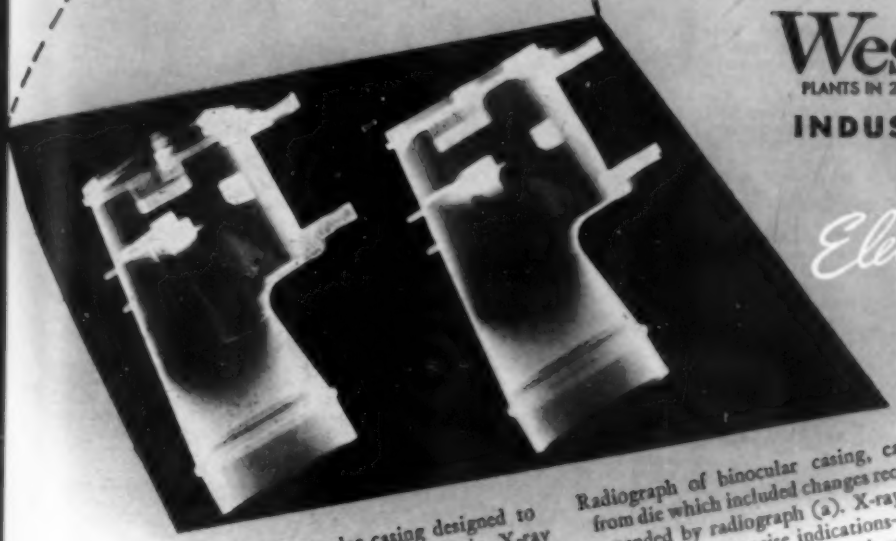


PAYING DIVIDENDS in Evaluation of Optimum Die Temperatures

Satisfactory production of die castings depends greatly upon the operating temperature of the die. Castings made in a cold die are usually more porous than those made at higher temperatures. An accurate record of the internal casting structure may be made by radiography. Castings selected and radiographed at various die temperatures, rapidly determine the minimum die temperature at which sound castings can be produced.

When the most satisfactory conditions are obtained and production of castings initiated, it is not safe to assume that ideal castings will be produced at all times during this run. Instruments, die setups, et cetera, may vary—resulting in changes of metal temperatures. Radiographs of production samples, selected at intervals, will check the consistency and quality of the castings produced.

An x-ray "spot-checking" will insure against the production of large quantities of castings which may have to be scrapped. J-02059



This is a binocular casing designed to withstand 9 lbs. to the sq. in. X-ray reveals unsatisfactory casting structurally porous. Radiograph suggests certain changes in vents and gates.

Radiograph of binocular casing, cast from die which included changes recommended by radiograph (a). X-ray provided rapid, precise indications—eliminating lengthy process of "developing".

Westinghouse

PLANTS IN 25 CITIES... OFFICES EVERYWHERE

INDUSTRIAL X-RAY

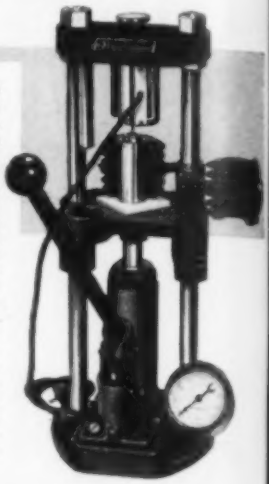
Electronics at Work

Buehler SPECIMEN PREPARATION EQUIPMENT AND SUPPLIES FOR THE METALLURGICAL LABORATORY

The items illustrated are selected from the complete Buehler line of equipment, tools and accessories for molding and finishing specimen mounts.

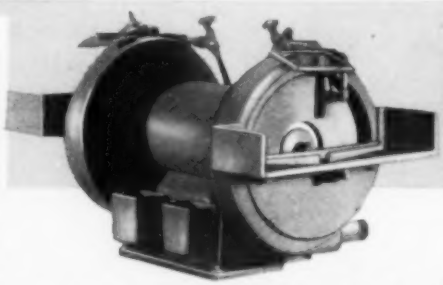
Abrasive Cut-off Machine, Model No. 1000, is a solidly built, heavy duty piece of equipment free from sideplay or vibration with capacity for cutting specimen sections up to 3-1/2". Cutting is done on the front of the wheel and is controlled by a convenient outside lever. The driving motor is a totally enclosed ball bearing, 3 hp. with a separate motor driving the self-contained cooling system. Overall dimensions of cabinet 31" x 47" x 64". Shipping weight, 1400 lbs.

Model No. 1010, a 1 hp. Cut-off Machine with cutting wheel mounted directly on motor shaft. Motor is ball bearing completely enclosed with sufficient power for fast cutting of samples up to 1" diameter. Overall dimensions 24" x 28" x 50". Shipping weight, 575 lbs.

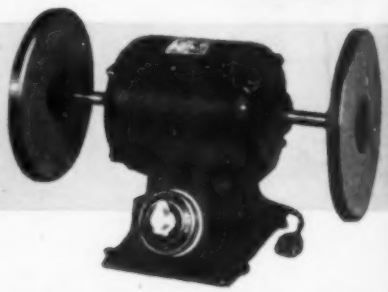


Specimen Mount Press No. 1315 has complete accessibility, no enclosed parts. Smooth performance permits speed and accuracy in operation. Solid heater can be raised and the cooling blocks swing into position without releasing pressure on the mold. This rapid cooling permits production of transoptic mounts in a few minutes. Shipping weight, 100 lbs.

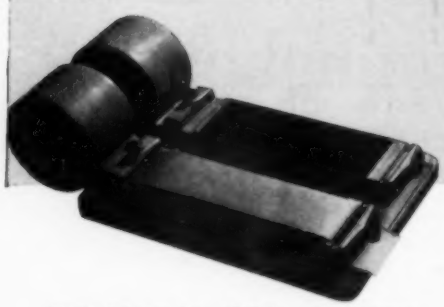
Heavy Duty Wet Power Grinder No. 1215, for coarse and medium coarse grinding. The entire surface of the 12" wheel is exposed for grinding; thus providing a wide range of grinding speeds. A self-contained recirculating cooling system supplies a soluble oil coolant independently to each wheel. A feature of this machine is its freedom from vibration. Shipping weight, 435 lbs.



Wet Power Grinder No. 1210, powered with a 3/4 hp. totally enclosed ball bearing motor has two 12" water cooled wheels fitted with closed-in guards and non-shatterable shields. Suitable for coarse and medium grinding. Shipping weight, 310 lbs.



Emery Paper Disc Grinder No. 1400, motor shaft is extended to provide four grinding surfaces for four grades of emery paper. Emery paper discs 8" diameter are held in place by a convenient two-piece clamp. Motor is 1/3 hp. with two speeds, 575 and 1150 r.p.m. Shipping weight, 75 lbs.



Hand Grinder No. 1410 is a most conveniently arranged two stage grinder. The grinding surfaces are 4-1/2" x 12-1/4" each with heavy 7/16" thick plate glass back. A reserve roll of 150 feet of emery paper is contained in drums for quick renewal of grinding surface. Base has gutter drains for surplus liquid in wet grinding operations. Shipping weight, 95 lbs.

Standard Polisher No. 1500. A complete unit with direct mounted 1/4 hp. radial thrust ball bearing motor. The 8" polishing disc is attached to a tapered arbor on the motor shaft by means of a stout sleeve. This sturdy construction and unusually smooth vibrationless operation helps to prevent pitting and amorphous film in polishing. The removable splash ring forms a convenient hand rest that aids the operator in precision work. A handy control lever on the mounted switch gives selective speeds of 575 and 1150 r.p.m. Shipping weight, 100 lbs.

Low Speed Polisher No. 1505-2, is particularly adapted to final stage polishing and for non-ferrous metal samples. The 8" disc is attached to a countershaft by a tapered sleeve with a long span between bearings, a construction feature that assures smooth operation. The selective speeds of 150 and 250 r.p.m. make this polisher perfectly adapted to the wax lap or lead lap polishing technique. Shipping weight, 105 lbs.

Either the standard or low speed polishers can be furnished in a single unit table model polisher No. 1516. A three unit table model No. 1540 is also available for maximum convenience in three stage polishing.

In the complete line of Buehler accessories and supplies for the metallurgical laboratory are found: Abrasive paper sheets, discs, and rolls in every grade • polishing solutions • polishing cloths • cut-off wheels and molding powders. Buehler service includes everything needed for preparing precision specimens from metallurgical samples, available from one reliable source.

Buehler Ltd.

A PARTNERSHIP

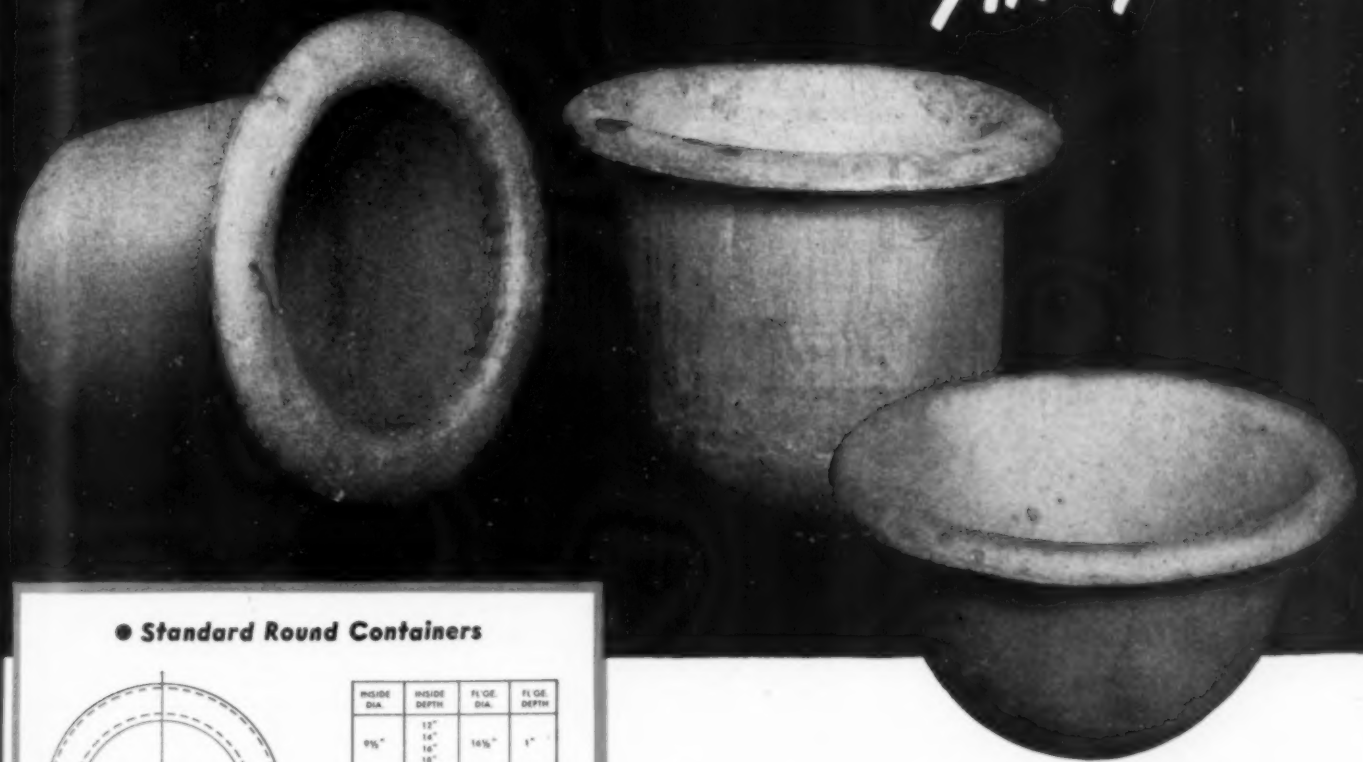
METALLURGICAL APPARATUS

165 West Wacker Drive, Chicago 1, Illinois

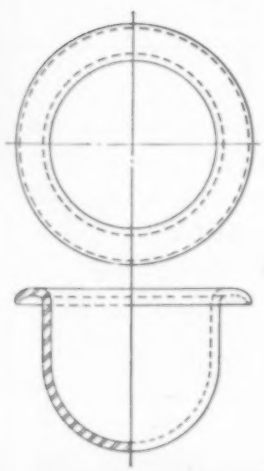
Get "Controlled Quality" Solution Pots in

FAHRITE

HEAT AND CORROSION *Alloys*



● ***Standard Round Containers***



INSIDE DIA.	INSIDE DEPTH	FLGE. DIA.	FLGE. DEPTH
9⅝"	12" 14" 16" 18"	16⅝"	1"
12"	12" 14" 16" 18" 20" 22" 24"	17⅝"	1⅛"
14"	14" 16" 18" 20" 22" 24"	20⅛"	1⅛"
16"	12" 15" 18" 21" 24" 27" 30"	22⅛"	1⅛"
18"	12" 18" 21" 24" 27" 30"	25"	1⅛"

"CONTROLLED QUALITY?" That means thorough laboratory analysis and inspection throughout every step of production. And that's why FAHRITE Heat Treating Solution Pots—and all FAHRITE castings—stand up longer under sustained elevated temperatures.

Standard patterns are also available for making many other FAHRITE Heat Treating Solution Pots in the grade exactly suited to your particular operating conditions.

Why not investigate FAHRITE's advantages for this and other applications in your plant? Complete information sent upon request.

The Ohio Steel Foundry Co.

SPRINGFIELD, OHIO

Plants: Lima and Springfield, Ohio

ENGINEERS
FOUNDERS
MACHINISTS

Free enterprise is the only way to constantly higher American living standards

HERE'S HOW TO ORDER COATED ABRASIVES THE EASY WAY!

NOW you can be sure you get what you ask for when you order Coated Abrasives. A new system of naming and labeling takes out all the grief. From now on Coated Abrasives by "CARBORUNDUM" are identified by the name of their end use. Specifications are clearly marked on labels and backing material. Here's how it works. To get the right coated abrasive for your job:

1—GET THIS BOOK

This new free book describes the new system of identifying, specifying and ordering Coated Abrasives by "CARBORUNDUM". It also gives complete information about Coated Abrasives by "CARBORUNDUM" and their uses.

2—LOOK AT THE BACKING

The man in the shop can tell what coated abrasive to requisition from stock just by a glance at the backing. Name and specifications are repeated often enough so that even small pieces are easily identified.

3—LOOK AT THE LABEL

The same information is repeated on the package label, so it's easy for the stock room to fill the requisition. And it's just as easy for Purchasing to make out repeat orders.

The first thing to do is write for your free copy of "Sanding and Finishing" if you have not yet received your copy. For additional information, consult your "CARBORUNDUM" representative or your distributor's salesman. The Carborundum Company, Niagara Falls, N.Y.

THERE IS A PRODUCT BY

CARBORUNDUM

TRADE MARK

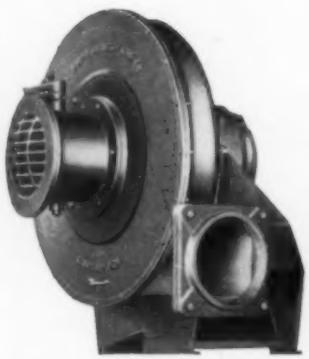
FOR EVERY ABRASIVE APPLICATION

("CARBORUNDUM" is a registered trade mark of and indicates manufacture by The Carborundum Company)

Simplicity...

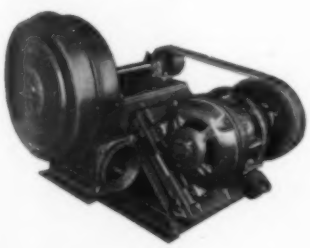
is the KEY NOTE in NORTH AMERICAN

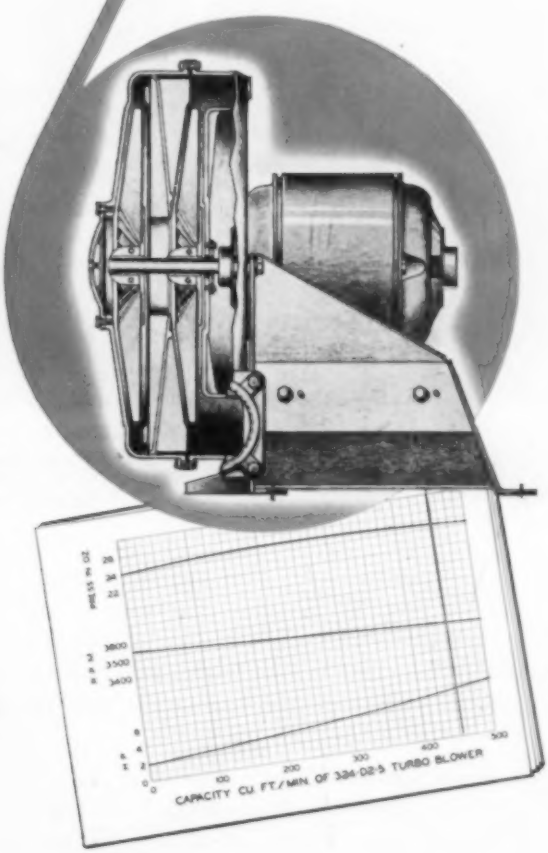
TURBO BLOWERS



(ABOVE) DIRECTLY CONNECTED. Butterfly valve on intake is standard equipment on larger sizes only. Smaller sizes equipped with intake guard—see section at right.

(BELOW) V-BELT DRIVEN. Used where 60 cycle A. C. current is not available.





(ABOVE) DIRECTLY COUPLED facilitates motor change. Blowers available in single or multiple stage—pressures from 8 to 32 oz. and volumes from 60 to 4300 cfm.

(BELOW) OIL PUMP ATTACHMENT for plants requiring small oil systems.

"NORTH AMERICAN for COMBUSTION"

THE NORTH AMERICAN MANUFACTURING COMPANY

MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL

BRANCH OFFICES *with* FIELD ENGINEERS *in* PRINCIPAL CITIES

CLEVELAND, OHIO

QUALITY ASSURES

A Good Name

Robert E. Peary

Few great achievements were ever attained the hard way, like that of Robert E. Peary. Pursued by adversity, plagued by successive failures at the threshold of triumph, each polar expedition attempted from 1886 to final success in 1909 was filled with tragedies that would stifle the aspirations of most men.

To the American public, Peary's discovery meant a great national victory; to the world's scientific societies, it presented a wealth of geographic and cosmic knowledge.

Thermalloy
ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO.
X-RAY CONTROLLED
American Brake Shoe Company
HEAT AND CORROSION RESISTANT CASTINGS

Even OLD MAN WEATHER didn't hurt these B&W IFB!

In the spring of 1942, eleven heat-treating furnaces, lined with B&W Insulating Firebrick, were moved outside an automobile plant to make room for war production. For three years they weathered summer rains and winter storms—with nothing for protection but a tarpaulin.

Reconversion brought them back into the plant. There was apparently no refractory deterioration—either from exposure to weather or from stresses incurred in moving.

The furnaces were started up, and in spite of the unusual weather treatment to which they had been subjected, have already operated for three months without any indication that the B&W Insulating Firebrick were in any way affected.

The story told above is typical — it proves that you can count on the durability of B&W IFB, in combination with their light weight and low heat conductivity to serve you faithfully in your plant.

B&W Insulating Firebrick have the lightest weight and lowest heat conductivity of any refractory in their class. Where B&W IFB have been installed, substantial savings in maintenance and fuel have been realized. See your local B&W Refractories Engineer about using these cost-cutting firebrick in your furnace installation.

R-227

B&W

Water-Tube Boilers, for Stationary Power Plants, for Marine Service . . . Water-Cooled Furnaces . . . Superheaters . . . Economizers . . . Air Heaters . . . Pulverized-Coal Equipment . . . Chain-Grate Stokers . . . Oil, Gas and Multifuel Burners . . . Seamless and Welded Tubes and Pipe . . . Refractories . . . Process Equipment.

BABCOCK & WILCOX

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
85 LIBERTY STREET, NEW YORK 6, N.Y.

War-born Ideas for Peacetime Products:

❶

❷

B&W TUBES SAVE TIME...

...CUT COSTS

Hydraulic lift jacks on Army Tankdozer ❶ and on material handling truck ❷ are both encased in B&W Tubing.

From a wide variety of war production requirements successfully solved by forming and/or machining ordnance items from B&W Mechanical Tubing come many cost-cutting, time-saving ideas for making better peacetime products. Bomb and rocket casings, elevator and catapult structures, aircraft struts, propeller shafts, hydraulic assemblies, tank treads and bushings, engine bearings . . . these are just a few of the war-born applications of B&W Tubing that suggest design and production shortcuts to improved quality, lower manufacturing costs and greater profits in new equipment for industrial and civilian uses.

Hundreds of different precision parts and structural members can be machined and formed from easy-to-work, dimensionally accurate B&W Tubing . . . and faster, more uniformly, in fewer operations and with less scrap loss than from solid stock. Now is the time to find out how you can take advantage of tubular parts in your products.

B&W can help you . . . in two important ways: By sharing its broad and diversified experience in matching tubing — both seamless and welded — to mechanical uses with your designers and engineers, and by supplying either kind of tubing of the proper analysis, size, gauge, temper and finish for each job. Get in touch with the nearest B&W office today for prompt reliable advice.

B&W

Other B&W Products

THE BABCOCK & WILCOX CO.

85 LIBERTY STREET • NEW YORK 6, N. Y.

Water-Tube Boilers, for Stationary Power Plants, for Marine Service • Water-Cooled Furnaces • Superheaters • Economizers • Air Heaters • Pulverized-Coal Equipment • Chain-Grate Stokers • Oil, Gas and Multi-fuel Burners • Refractories • Process Equipment.

BABCOCK & WILCOX SEAMLESS & WELDED TUBES

THE BABCOCK & WILCOX TUBE COMPANY

WELDED TUBE DIVISION ALLIANCE, OHIO • SEAMLESS TUBE DIVISION BEAVER FALLS, PA.

TA-1344

"With GULF CUTTING OILS we get greater production, longer tool life, and better finishes"

says this Superintendent

Machine Shop Superintendent (center) consulting with a Gulf Service Engineer on results with Gulf L. S. Cutting Base in machining valve stems.

"AFTER SWITCHING to Gulf Cutting Oils, we noted a general improvement all over the shop in production, tool life, and finish," says this Superintendent. "By the use of Gulf L. S. Cutting Base on this machine, we increased output about 40 per cent, and in addition secured longer tool life and a much better finish on the work."

Gulf quality cutting oils can give you a vital advantage in machining efficiency that may help you make substantial cuts in unit production costs. Here's the important reason: Every Gulf Cutting Oil has specific properties which insure better performance on certain types of machining jobs!

It will pay you to find out quickly the full possibilities of Gulf's production-proven cutting oils in your shop. Call in a Gulf Service Engineer today and let him show you how they can help you with your machining problems. Write, wire, or phone your nearest Gulf office. For your copy of the booklet "Gulf Cutting Oils," send the coupon below.

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Please send me, without obligation, a copy of the booklet, "Gulf Cutting Oils," which includes a helpful Machining Guide.

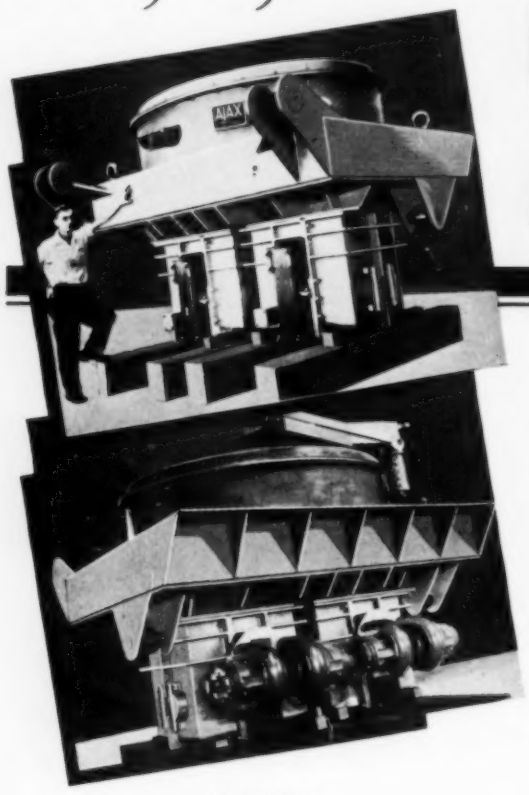
Name.....

Company.....

Title.....

Address.....

Low Frequency INDUCTION MELTING FURNACE *by* AJAX*



FRONT AND BACK VIEWS

THIS unit (the largest of its kind ever made for melting aluminum alloys) is powered with 500 kilowatt three-phase, 60-cycle alternating current, melts over 2500 pounds of aluminum alloy per hour and allows to cast ingots up to 6000 pounds individual weight. Tilting is exactly around the pouring spout and casting speed is adjusted within close limits by hydraulic rams with sensitive pump control.

Temperature, of course, is also automatically regulated and there is no chance for overheating the bath at any time during the melting cycle.

• Ajax Tama-Wyatt Induction Furnaces are made in a wide range of sizes to meet the demand for large volume or small special lots of aluminum alloy ingots. Ajax Tama-Wyatt Furnaces can be operated continuously, without frequent interruptions previously necessitated for reconditioning melting channels.

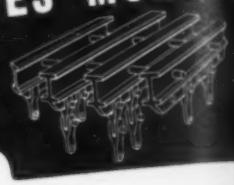
AJAX ENGINEERING CORPORATION
BOX 1418, TRENTON 7, N. J.

*REG. U. S. PAT. OFF.

AJAX TAMA-WYATT **INDUCTION MELTING FURNACE**

Associate Companies: **AJAX METAL COMPANY,** Non-Ferrous Ingot Metals and Alloys for Foundry Use
AJAX ELECTROTHERMIC CORP., Ajax Northrup High Frequency Induction Furnaces
AJAX ELECTRIC CO., INC., The Ajax-Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax Wyatt Induction Furnaces for Melting

STERMET HEAT TREATING EQUIPMENT SAVES MONEY!



Case #14

the problem:

To provide a top hanger mechanism for suspending heavy loads in deep pit furnaces. Hangers and work both oil quenched from 1600-1700°F. Original equipment sketched at right consisted of I-beams with a web extension on lower face with which special suspension links engage. Service life unsatisfactory because of cracking and sagging, resulting from combined influences of sustained loading and quenching strains.

the answer:

A combination of tubular beams perforated to effect maximum uniformity of cooling — strong to carry sustained loading and *with suspension link engagement holes above the neutral axis* to reduce stress on lower half of beams.

the result:

Highly satisfied user-service life when recently inspected — four times the original equipment and in customer's words, "Still in perfect condition".

District Engineering Offices

Dayton	St. Louis, Mo.	Detroit
Louisville	Philadelphia	Houston
Portland, Ore.	Buffalo	Chicago
New York City	Cleveland	Pittsburgh
Milwaukee	Springfield, Mass.	
Indianapolis		

STERLING ALLOYS, Inc.
WOBURN, MASS.

Reduced from 3 hours to 30 seconds

BUSHING ASSEMBLY TIME

by a Simple Shrink Treatment in a

Deepfreeze

Industrial Chilling Machine

Courtesy W. F. and John Barnes Co.

SHRINK-FIT ASSEMBLY PROVES 360 TIMES FASTER THAN FORMER PRESS-FIT METHOD

Here are cold-treating results that speak for themselves. This manufacturer formerly used an arbor press to insert 8620 steel bushings into cast iron gear housings. Time required to complete the assembly was three hours. This method proved costly. Manhours were wasted. Part spoilage was common. Production in general was retarded.

To overcome these conditions shrink-fit was substituted for press-fit. Bushings were subjected to an hour's treatment in a Deepfreeze Industrial Chilling Machine. They were then easily inserted into the housing by a single operator. Today the actual time required to complete each assembly is 30 seconds. In addition, the employment of the shrink-fit method has freed manpower for other duties. Part spoilage has been eliminated, plant production increased.

Job FACTS

Operation—Assembly of bushing into quill housing.

Male Part—8620 steel bushing.

Female Part—Cast iron quill housing.

Former Method of Assembly—Arbor press and pulling in by screw.

Time Formerly Required For Assembly—Three hours.

Present Method of Assembly—Shrink-fit; bushings subjected to sub-zero treatment in Deepfreeze Industrial Chilling Machine for one hour period and inserted into housing upon removal.

Present Time Required For Assembly—Two bushings per minute.

Remarks—In addition to increasing the rate of assembly over 360 times the shrink-fit method conserves manpower, eliminates part spoilage and improves overall production.

HOW TO DETERMINE THE RESULTS OF APPLYING COLD TREATING TO YOUR PRODUCTION . . . . .

You, too, can cold-treat in a Deepfreeze unit with equal success. Not only to speed the assembly of metal parts, but also to harden, stabilize and test metals and metal parts, and for numerous other operations. You can determine the various uses and results of applying cold treating to your production by contacting Deepfreeze Engineering Service. This group of industrial refrigeration experts is prepared to furnish you with the latest cold treating information without obligation.

FREE Valuable Cold Treating Data, including actual performance stories, detailed methods and procedures, charts, tables, list of users and additional information that you can use to advantage, all bound into this new Deepfreeze Book. Send for your copy today.

Deepfreeze

DEPT. MP-12, 2301 DAVIS ST.
NORTH CHICAGO, ILLINOIS

SOME "FALLS BRAND" ALLOYS

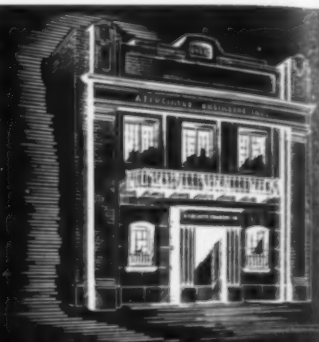
Magnesium Aluminum 2%
Magnesium Aluminum 10%
Magnesium Copper 10%
Manganese Aluminum 5%
Manganese Aluminum 10%
Manganese Aluminum 20%
Manganese Aluminum 25%, Metallurgical Grade
Manganese Bronze Hardeners
Manganese Copper 30%, Grade A
Manganese Copper 30%, Grade B
Monel Ingots
Monel Shot
Nickel Aluminum 20/80
Nickel Copper Aluminum 25/25/50
Nickel Copper 15/85
Nickel Copper Ingots 30/70
Nickel Copper Shot 30/70
Nickel Copper Shot 50/50
Nickel Iron 50/50
Nickel Shot
Nickel Silver
Nickel Tin 50/50
Silicon Aluminum 12%
Silicon Aluminum 25%
Silicon Aluminum 50/50
Silicon Bronze Hardeners
Silicon Bronze Ingots
Silicon Copper 10%
Silicon Copper 15%
Silicon Copper 20%
Silicon Copper 30%
Silicon Copper Aluminum 25/25/50
Silicon Titanium Aluminum

This partial list is but a few of the many alloys we make. Each is for the specific purpose of adding quantities of high melting point metals to standard alloys.

There's a
Falls Brand Alloy
For Every Foundry Use.

Our Telephone Number It's Buffalo Riverside 7812-3-4

NIAGARA FALLS SMELTING & REFINING CORPORATION
America's Largest Producers of Alloys
BUFFALO 17, NEW YORK



MANAGEMENT COUNSEL

Our services provide the combined talents of registered licensed, professional industrial and mechanical engineers, accountants, architects, structural, civil and hydraulic engineers, electrical, heating, ventilating, air conditioning, chemical, foundry and metallurgical engineers to work closely with members of your staff in helping to build a more effective business organization.

Illustrated folder on request

- Industrial Engineering
- Methods
- Plant Layout
- Production Flow
- Work Standards and Costs
- Job Evaluation
- Wage Incentives
- Architecture
- Structural Engineering
- Civil Engineering

The successful future of many a business hangs on the thread of making a decision to do something today

ASSOCIATED ENGINEERS, INC.
Joseph C. Lewis, President

230 EAST BERRY STREET
Fort Wayne 2, Indiana

AEI

CLUTCH PART FOR OIL-WELL HOIST

This 15-kw electronic heater, similar to the one used by Cardwell Mfg. Co., Inc., Wichita, Kansas, is one of a number of sizes produced by G-E for industrial uses.

HARDENED IN 17 SECONDS with Electronic Heating

WHEN a big production hoist yanks thousands of feet of oil well rods and tubing to the surface, much of the strain must be borne by the clutch plate jaws.

To harden those jaws, for longer life, without hardening the entire clutch plate, was a problem of the Cardwell Manufacturing Company, oil rig manufacturer.

We recommended electronic heating. Now, by placing the clutch jaw in an inductor coil connected to a 15-kw G-E electronic heater, the part is raised to the desired temperature ***in only 17 seconds***. A water quench completes the hardening process.

Since no scale or distortion results from the electronic heat treatment, the precision machining of the parts can be completed before hardening.

Whether ***your*** production problems involve the application of heat to a closely limited zone or the brazing or soldering of some complicated assembly—find out, now, how a G-E electronic heater can improve your product quality and increase your output. For details, get in touch with the G-E heating specialist in your nearest principal city, or write General Electric Company, Schenectady 5, N. Y.

BUY WAR BONDS

No. 11 in a series of case studies on the accomplishments of G-E electronic heaters

GENERAL ELECTRIC

ELECTRONIC HEATERS

clean 'em WELL..

clean 'em FAST..

with PANGBORN AIRLESS ROTOBLAST*

NO matter how large or small a casting may be . . . no matter how simple or intricate its design or whether it is tough or "fragile" . . . no matter what kind of metal or alloy it is made of—it can be economically cleaned on a production basis by the Pangborn Airless ROTOBLAST Method.

Pangborn engineers have had the kind of experience that makes it possible for them to go right to the heart of the toughest foundry problems—and come up with the most efficient and economical solution. They have developed special basic equipment to meet many different cleaning needs, with handling methods geared to individual plant production lines—saving countless hours of handling, improving the uniformity of finishing, reducing rejects and lowering cleaning costs.

Pangborn ROTOBLAST Barrels, Tables, Cabinets and specially designed installations are cleaning castings better, faster and cheaper in foundries in every part of the country. "Come to Pangborn" for bulletins and specific information about the benefits of Pangborn ROTOBLAST Method for *your* foundry.

*Trademark of Pangborn Corporation

PANGBORN

WORLD'S LARGEST MANUFACTURER OF BLAST CLEANING AND DUST COLLECTING EQUIPMENT

PANGBORN CORPORATION • HAGERSTOWN, MD.

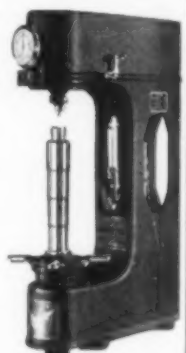
CLARK

TOMORROW'S ACCURACY TODAY

Gives Continued Accuracy, Rapid Measurements

THE CLARK has everything you want in a hardness tester—direct reading precision dial, durable construction, ease of servicing. Three standard models shipped complete with weights, dust protectors, diamond and steel penetrators, test blocks, and anvils.

CLARKATOR CHECKS DIAL INDICATORS with micrometer speed and sine bar accuracy. Easy to operate—just four simple steps. Complete instructions, permanently fastened to base.



CLARK HARDNESS TESTER

MASTER DIAMOND CHECKING SET eliminates hardness tester errors. Consists of a master diamond penetrator and two test blocks. Precision is assured over a long period because the set is used only for checking. Furnished in leather case.

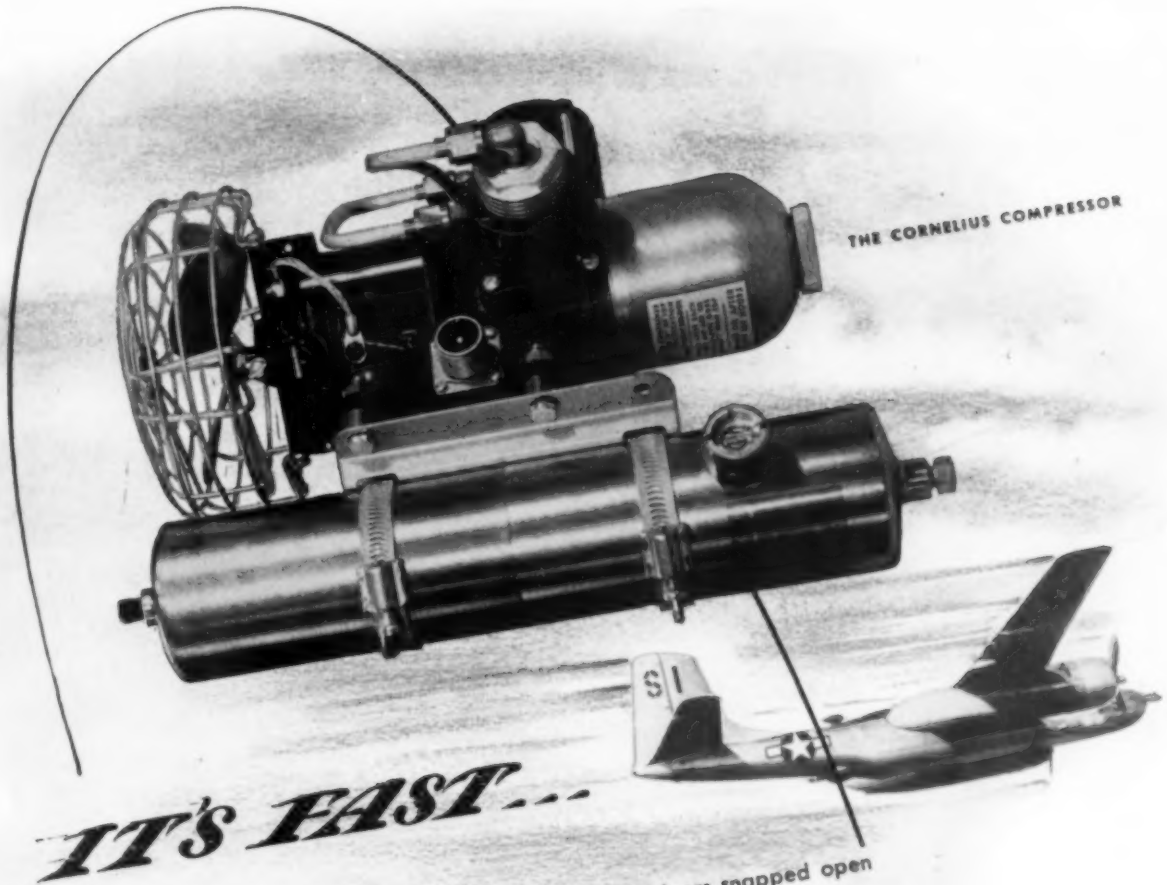
Learn the truth about hardness testing! This 20-page reference manual (right) contains information on history, theory, practice, and equipment for modern hardness testing. Available to executives without charge. Write Dept. MMS today!

MASTER DIAMOND CHECKING SET

CLARKATOR CHECKS DIAL INDICATORS

CLARK INSTRUMENT, INC.

10200 Ford Road • Dearborn, Mich.



THE CORNELIUS COMPRESSOR

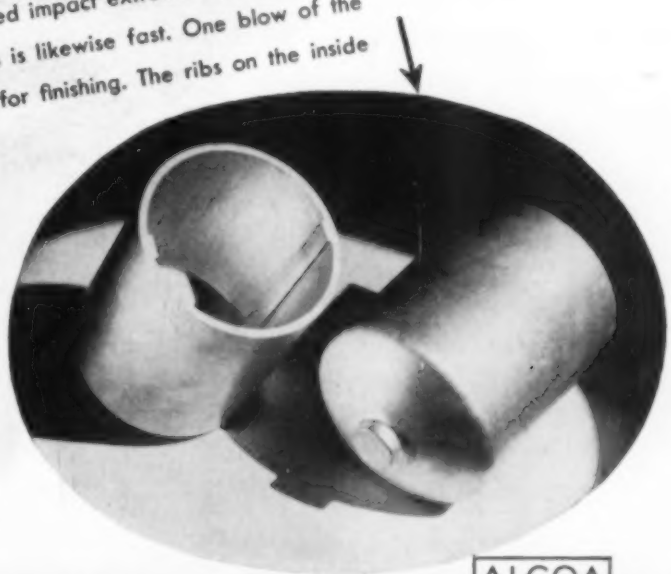
IT'S FAST...

When Tokyo was the target, bomb-bay doors snapped open in 7/10ths of a second, sparing bomber crews the former, agonizing 15-second wait. Air, stored at 1,500 pounds pressure, actuated the doors.

Heart of this new, fast system is the Cornelius compressor—little but mighty—weighing only 10 pounds. And storing that air is an aluminum cylinder, fabricated by threading together the two Alcoa heat-treated impact extrusions you see here.

Production of these aluminum cylinder halves is likewise fast. One blow of the impact extrusion press and the part is ready for finishing. The ribs on the inside form bosses in which piping is attached.

Alcoa Aluminum impact extrusions may help speed up your production and reduce costs. We'll help you find out. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Bldg., Pittsburgh 19, Pennsylvania.



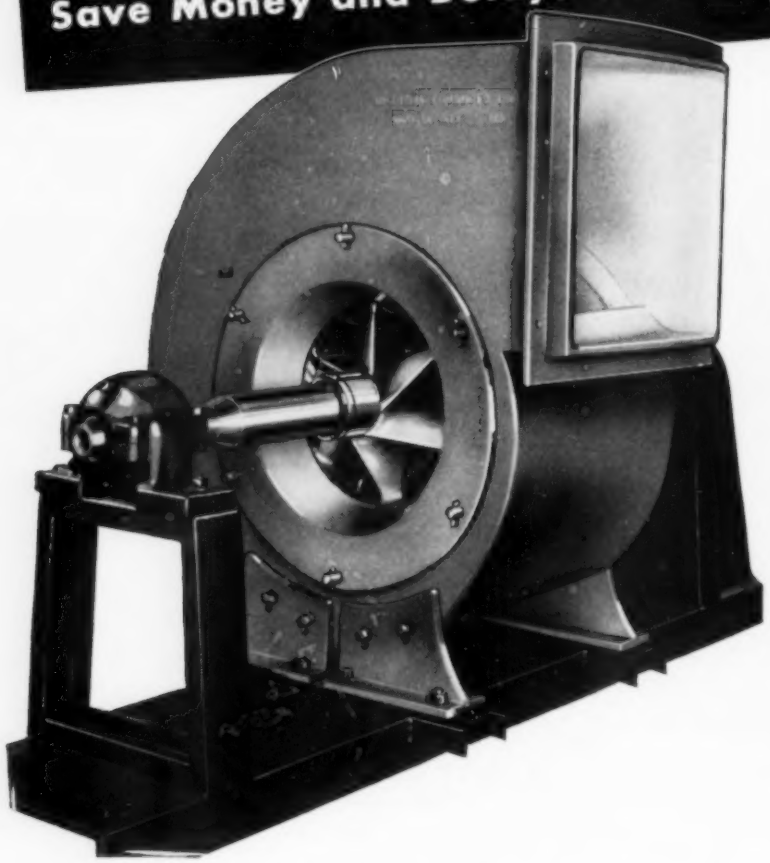
Thick walls of heat-treated Alcoa Aluminum provide great strength.

ALCOA FIRST IN ALUMINUM

ALCOA ALUMINUM

CAN THIS *TRULY* HIGH TEMPERATURE FAN

Save Money and Delays for You?



Made of heat-resistant alloys, MICHIANA Fans withstand temperatures as high as 1800° Fahr. This insures low-cost long-time service with minimum delays and replacement troubles.

Distortion and unbalanced conditions are eliminated because of the MICHIANA design with vital operating parts so assembled to allow for free and independent expansion and contraction.

These fans are now available—let us know your requirements . . . MICHIANA PRODUCTS CORPORATION, Michigan City, Indiana.

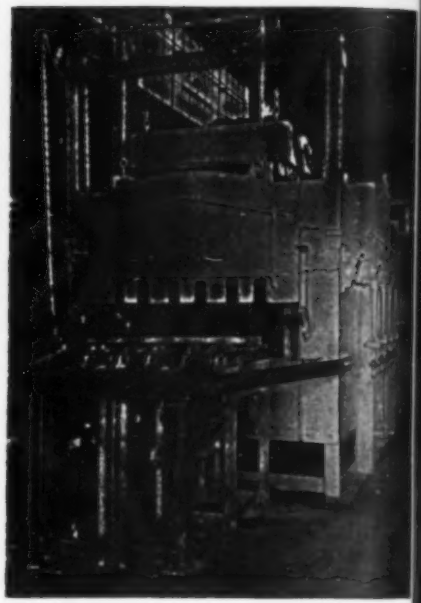
MICHIANA
HIGH TEMPERATURE
FANS

Write for new Bulletin 645.

BELLEVUE

Job-Designed

FURNACES



● In the construction of Bellevue Furnaces, painstaking consideration of the job to be done comes first. Every factor must be evaluated, every condition studied. Only then do Bellevue engineers attempt design and recommendation of furnace type.

The soundness of that policy is being demonstrated in plant after plant. Hundreds of executives in scores of varied companies have proved, to their own satisfaction, the efficiency, speed, high production level and operating economies of Bellevues that were "designed" for the job.

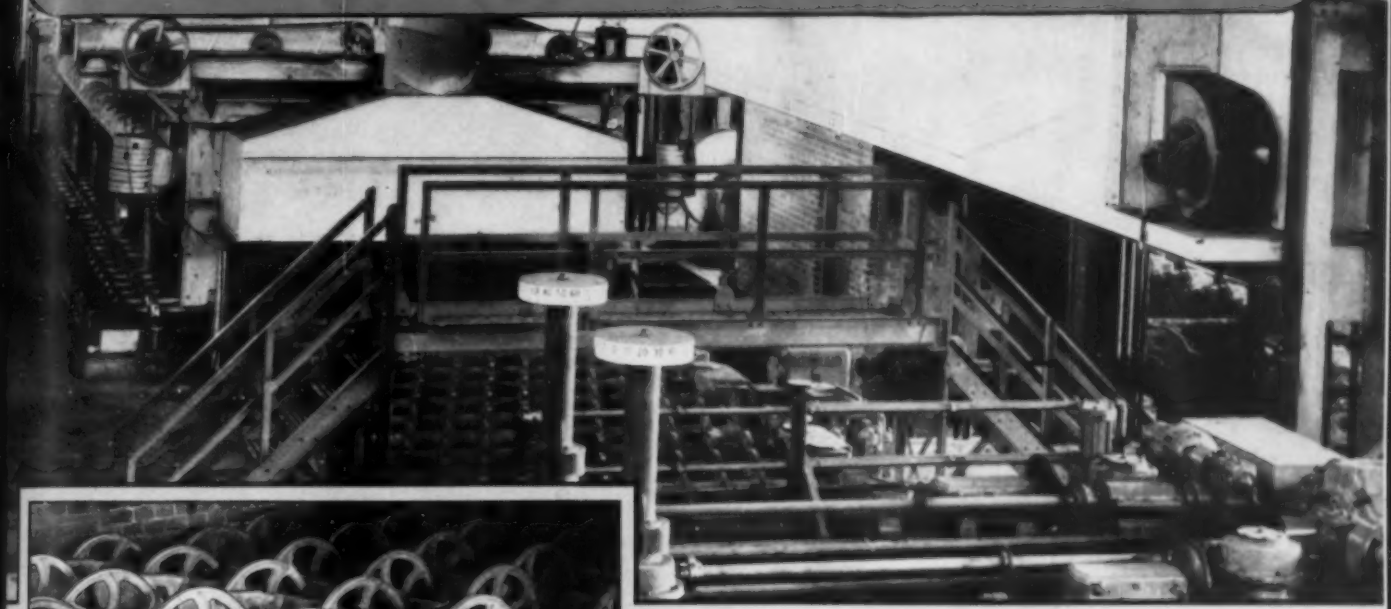
You, too, will find Bellevue experience and facilities a profitable investment for your own furnace needs.

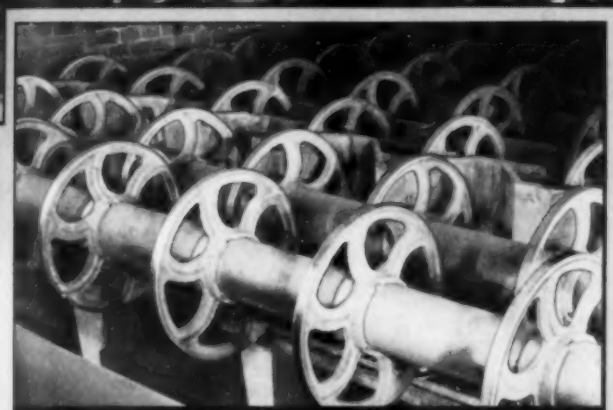
Send for full details.

BELLEVUE INDUSTRIAL FURNACE CO.

2980 Bellevue Ave. Detroit, Mich.

Castings by DRIVER-HARRIS
For Heavy Loads at High Temperatures





Close-up of the shafts furnished by Driver-Harris in the conveyor of the Lukens Steel Co. furnace.

HEAT TREATING FURNACE
COMBINES MANY UNUSUAL FEATURES

An unusual feature in this heat-treating furnace installed by Surface Combustion at the Lukens Steel Company of Coatesville, Pa. is use of the inside roller-bearing dry conveyer shafts which carry loads up to 70 lbs. per sq. ft. at temperatures to 1900° F.

The furnace, which is 11 ft. wide inside, is used to heat treat heavy plates ¼" to 1½" thick. Its 123 ft. length consists of a 75 ft. *heating zone* and 48 ft. *cooling zone*. In spite of high loads and steep temperatures, the 54 inside roller-bearing shafts in the heating zone are only 5⅜" in diameter with ⅜" wall. The cooling zone has 36 water-cooled outside bearing shafts. From hot through cold zones the shaft speeds vary from 5 to 150 fpm.

Because these extremely rugged operating conditions require metal parts which combine excellent oxidation resistance with great strength at elevated temperatures *castings by Driver-Harris were specified*. And all the alloy shafts, bearings, discs, etc., were designed, cast, machined and assembled by Driver-Harris.

Unusual . . . or usual, if you have a heat-treating problem, tell us about it. Our engineers are always at your service. Write for a copy of Catalog F-40.

*Trade Mark Reg. U. S. Pat. Off.

NICHROME*
CHROMAX*
CIMET*
are made only by

Driver-Harris COMPANY

HARRISON, N. J.

Branches: Chicago • Detroit • Cleveland
Los Angeles • San Francisco • Seattle

Pen-Kote 500 COVERS WET SURFACES AS READILY AS DRY

Protects ALL Surfaces Against Acids, Alkalis and Moisture

With Pen-Kote 500—the ***different*** type of maintenance paint—wet floorboards, walls and equipment of every kind can ***all*** be painted as readily as dry, with obvious savings in time and trouble. It goes on smoothly, adheres perfectly, and gives full protection against acids, alkalis and moisture.

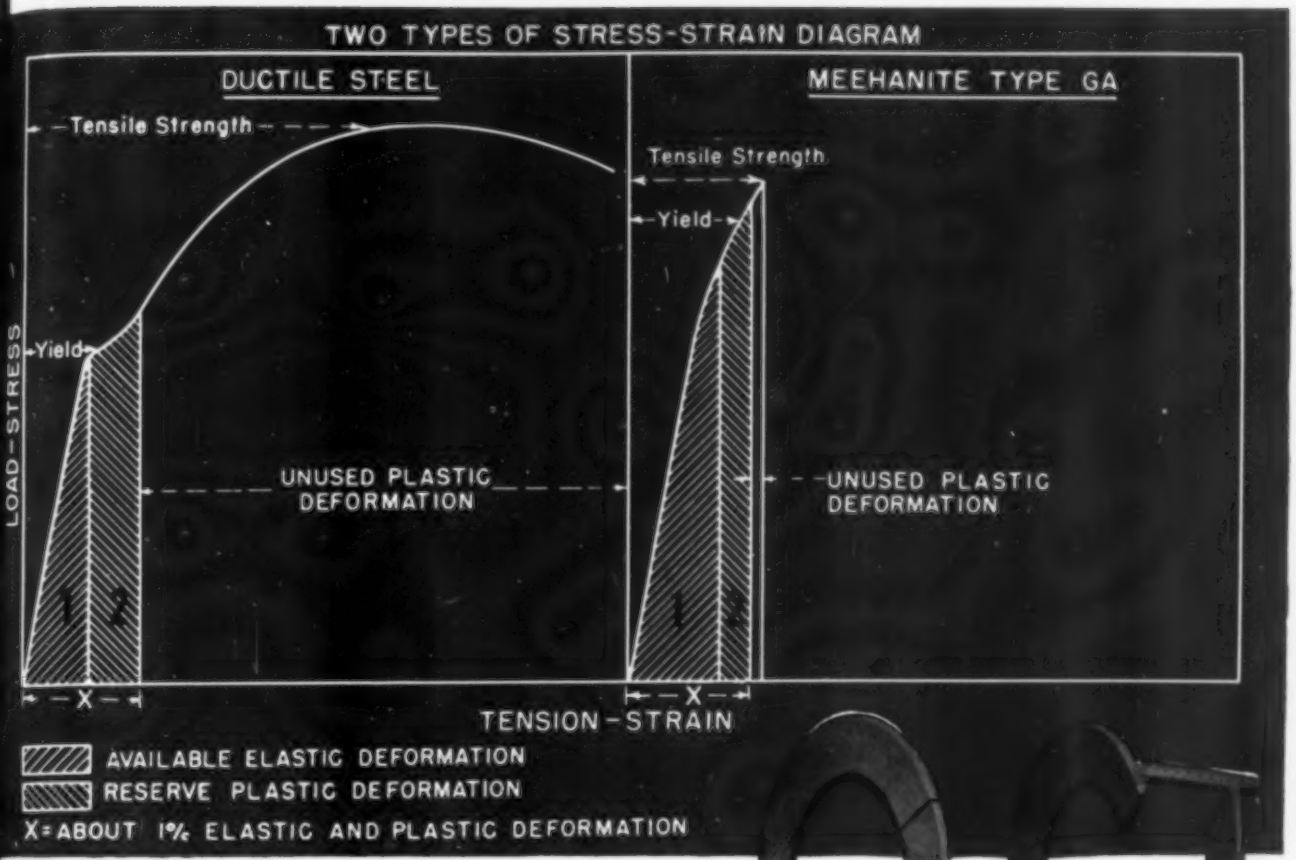
As free-working as regular house paint, Pen-Kote 500 is exceptionally easy to apply—and it sets in 30 min. or less to a hard but flexible film of plastic. Only two coats are needed under the toughest conditions; a single coat is often sufficient.

For these reasons alone, Pen-Kote 500 merits your consideration for all applications requiring durable protection against corrosion and rot. This paint has other advantages too: It's truly ***odorless.*** It's ***free-working even on hot surfaces;*** forms a perfect coating without blistering or hardening on the brush. It ***can be recoated*** as often as desired without blistering. And it's a ***perfect sealer;*** asphalt, pitch, and other paints will not bleed through Pen-Kote 500. Furnished in black, white, gray and standard identification colors.

For perfect protection at minimum cost, more quickly and easily applied—specify Pen-Kote 500. Full information on request.

Pen-Kote PRODUCTS

PENINSULAR CHEMICAL PRODUCTS CO.
6795 EAST NINE MILE ROAD
VAN DYKE • MICHIGAN



MEEHANITE CASTINGS ARE TOUGH!

This 1" thick section was cut from a heavy Meehanite casting. It was possible to split the piece as shown 3½" before fracture.

FACTS, FIGURES, DATA, AVAILABLE AND RELIABLE FOR THE USERS OF MEEHANITE CASTINGS

In engineering design the ultimate breaking strength of any material is rarely used. Designers require safety in service, not failure. There is a considerable gap between the yield point and the ultimate strength.

The stress-strain diagrams plotted from a tensile test of mild steel and Type GA Meehanite appear as shown above.

Steel shows both a higher ultimate strength and elongation value than Meehanite. The important point, however, is how much of these values can be used in unit design.

The diagrams reveal three distinct areas:

1. *Stress absorbed during elastic deformation. This has relation to the Modulus and Yield strength.*
2. *Stress absorbed during elastic and plastic deformation which has some relation to the reserve of plasticity available against sudden fracture.*
3. *Plastic changes recording deformation during failure.*

Areas 1. and 2. illustrate in a general way, the relative capacity of both materials to absorb working stress in service up to approximately 1% plastic deformation, which is as much as any normal engineering construction can endure.

They show that to this extent Meehanite, despite its lower ductility, does have as large an area for plastic adjustment to distribution of the load as the so-called ductile metals.

This explains why Meehanite is finding wider engineering applications in structures normally calling for high elongation and reduction of area values.

MEEHANITE RESEARCH INSTITUTE
NEW ROCHELLE, N. Y.

Enough LITHIUM here for 200 lbs of SUPERIOR CASTINGS

LITHALOYS

THIS chunk actually contains only 2% **LITHIUM** — approximately ½ ounce. The other 98% consists of Cu, Zn, or bronze proportioned to match your melt. Yet this small quantity of metallic **LITHIUM** is sufficient to remove hydrogen and other gases, oxides, sulphides and other non-metallic impurities from a 200 pound melt of copper or bronze.*

LITHIUM metal works because it combines with these impurities forming non-metallic compounds of low specific gravity, insoluble in the melt and having a melting point below the casting temperature of the metal. These compounds volatilize, or flux out quickly, thus increasing the fluidity which often permits lowering pouring temperature. As a result, your castings are clean and sound, possessing optimum physical characteristics.

LITHIUM treatment requires no new technique, no new equipment, no special training for your crew. Our technical staff and our own casting facilities can be placed at your disposal.

*Tin bronze or silicon bronze.

LITHALOYS CORPORATION

444 MADISON AVENUE, NEW YORK 22, N. Y.

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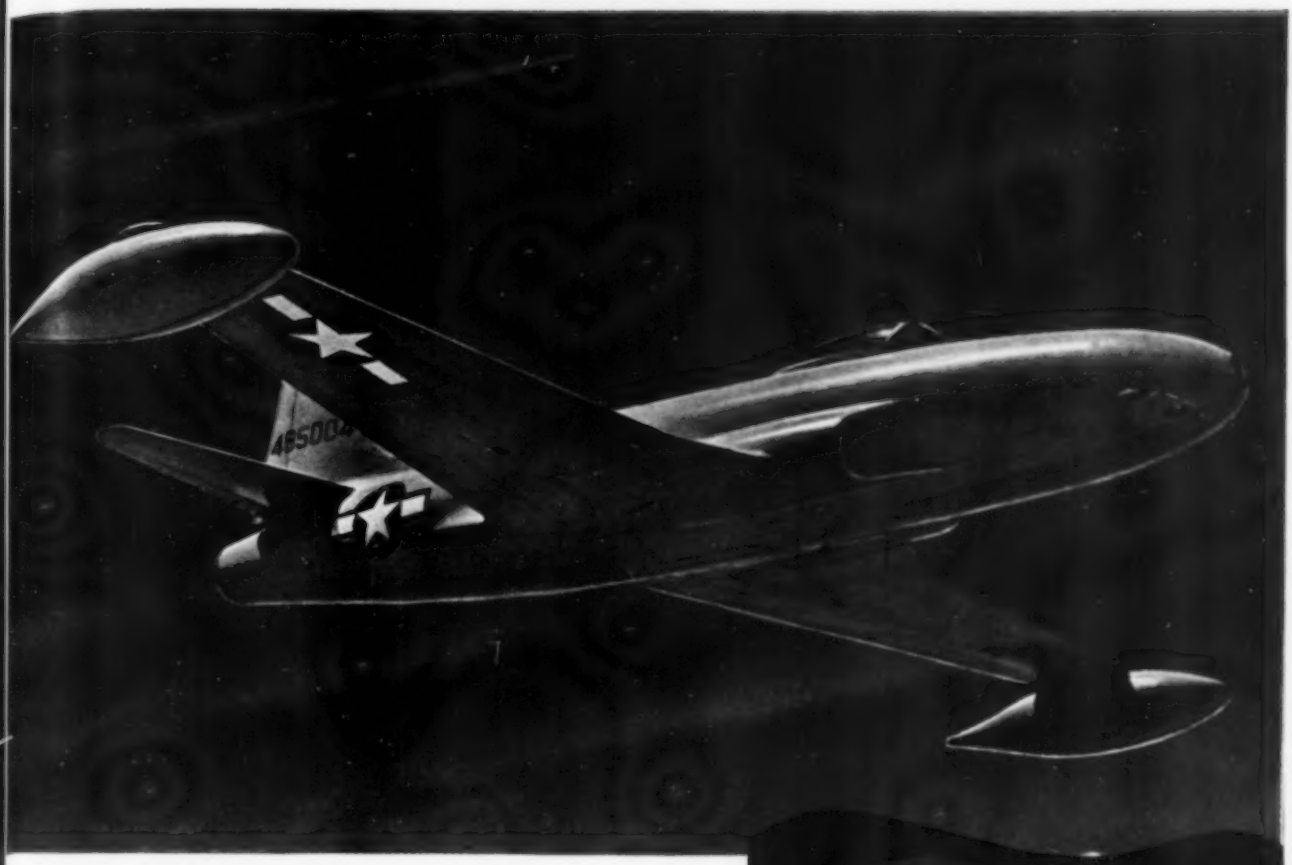


Blades for Breathing

Quantity Production Jet Turbine Blades Solved by Microcast Process

Flying higher and faster than ever before possible, jet propelled aircraft such as the Lockheed Shooting Star P-80 "breathe" vast quantities of air—supplied by turbine-driven compressors.

In designing blades for these turbines it was necessary to use high melting point, extremely hard alloys such as *Vitallium, capable of withstanding the tremendous force and heat of jet blasts. High melting point alloys being difficult and expensive to machine were a problem in quantity production. The answer—MICROCAST, the process of precision casting high melting point non-machineable alloys which has proven so successful in producing specialty blades by the millions for gasoline aircraft turbo-superchargers.

COPYRIGHT 1945 BY AUSTENAL LABORATORIES, INC.

*VITALLIUM
A non-machineable alloy

The MICROCAST Process is foremost in the precision casting of specialty blades for power development units. Engineers are finding that MICROCAST, by permitting the economical quantity production of high melting point alloy castings, has opened the way to many design improvements particularly where extreme resistance to wear and stress is required.

The precision process originated by Austenal Laboratories, Inc., for the production of castings of intricate design where accurate dimensions and surface smoothness are absolutely essential. Small castings produced by Microcast Process require little or no machining. Consider Microcast in your product plans.

MICROCAST

AUSTENAL LABORATORIES, *INC.*

224 East 39th Street, New York 16, New York
5932 South Wentworth Avenue, Chicago 21, Illinois

Two new hard-facing electrodes for A.C.-D.C. ELECTRIC APPLICATION

BARE STOODY 6 and Stoody 1 for oxy-acetylene application have long been accepted as tops for protection against heat, abrasion, corrosion and impact. Now—with the two new, coated rods you get the same physical properties, but with *the advantage of A.C.—D.C. electric* application!

USE THE NEW COATED STOODY 6 and 1 on your heavy equipment or where oxy-acetylene is impractical because of size limitations of the workpiece. The new coated rods are also useful where physical properties of parent metal must be retained or where heat treatment is undesirably affected by torch flame.

LOW IRON PICKUP. When applied electrically with straight polarity, base metal pickup is held to an absolute minimum, *thus preserving full hardness, heat and corrosion resistance.* Spectrographic analyses show electric deposits identical to acetylene deposits.

CHARACTERISTICS

High build-up. Low penetration. Rapid burn-off rate. Good slag coverage. Easy slag removal.

STOODY 6 possesses red hardness, corrosion and abrasion resistance as well as *sufficient ductility to withstand heavy impact.*

STOODY 1 resists corrosion . . possesses extreme hardness even at red heat, with resulting wear resistance. Especially recommended for conditions involving acute abrasion.

TYPICAL APPLICATIONS

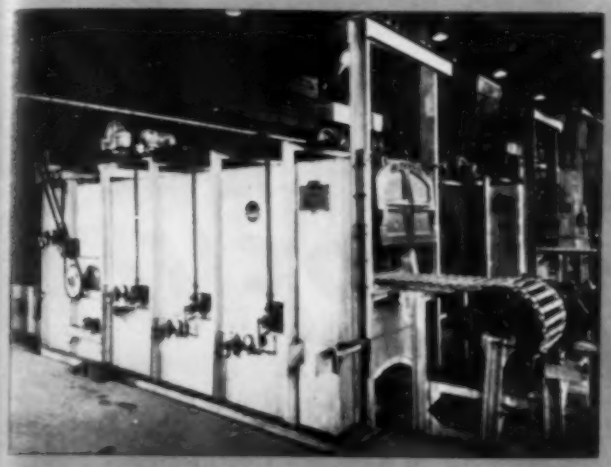
Vegetable and fish oil expeller parts, heavy hot punches, capstans, heavy blades for cutting scrap or shearing hot steel, blast furnace bleeder valves, blowing engine gas valves and seats, heavy mill guides, hot trimming dies, blanking dies, forming dies, stoker screws, coke oven push shoes, hot clinker conveyor screws, etc.

NO CHANGE IN PRICE

Both coated electrodes for electric application and bare rods for oxy-acetylene application sell for the following prices: 3/16" dia., $4.25 per lb. 1/4" dia., $3.75 per lb. Prices are reduced on quantity purchases. All prices f.o.b. distributor's warehouse or Whittier, California.

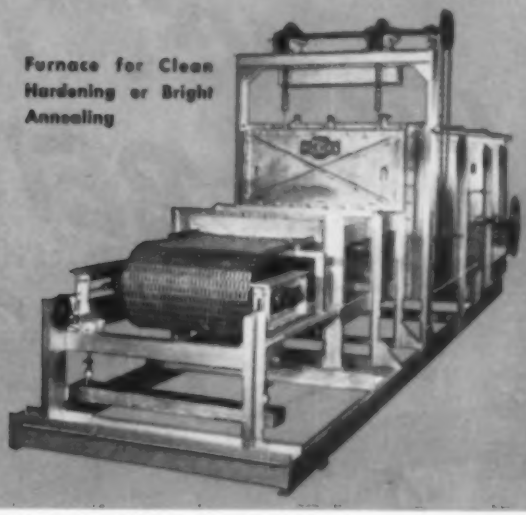
STOODY COMPANY
1146 WEST SLAUSON AVENUE • WHITTIER, CALIFORNIA

STOODY HARD-FACING ALLOYS
Retard Wear Save Repair



Recirculated Air Tempering and Stress Relieving Furnace

Furnace for Clean Hardening or Bright Annealing



DREVER CONTINUOUS FURNACES

CUT PRODUCTION COSTS

The Drever Company has designed and constructed many types of continuous furnaces to meet a wide variety of specific production requirements.

These installations include atmosphere and non-atmosphere types, fired by any fuel or electricity, with proper quenching equipment where necessary.

We would be pleased to discuss details at your convenience.

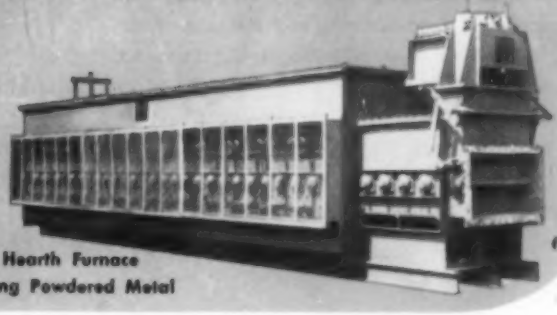
THE DREVER CO.

790 E. VENANGO ST., PHILA. 34, PENNA.

PRESSURE QUENCHES CONTINUOUS FURNACE LINES • HEAT TREATING FURNACES

NEW YORK & NEW ENGLAND: GERALD S. DUFF, 68 CLINTON AVE., NEWARK 3, N. J.

Hardening and Annealing Furnace



Roller Hearth Furnace for Sintering Powdered Metal

IT'S NEW! IT'S BETTER! IT'S DIFFERENT!

BETHLEHEM Black Giant TOOL STEEL

(GRAPHITIC)

Here's news of smashing interest to users of tool steels. News that can be headlined in three words: Bethlehem Black Giant.

Many months of chemical, metallurgical, experimental, and testing work preceded the announcement of Black Giant Tool Steel; but now the facts are established. Facts like these:

- Black Giant has superlative machining qualities.
- An oil-hardening tool steel, it responds readily to heat treatment.
- It has much greater depth of hardness than ordinary graphitic steels.
- It has better non-deforming properties.
- Its self-lubricating qualities mean lower coefficient of friction; longer life in tools requiring high resistance to abrasive wear.

These are but a few of Black Giant's many advantages. There are others that you will want to hear about. For further details, check with the nearest Bethlehem office or distributor. *Black Giant warrants an immediate investigation.*

TYPICAL ANALYSIS

C	*Mn*	*Si*	*Cr*	*W*
1.40	0.90	2.20	0.45	0.50

TYPICAL USES

Machined dies; plug or ring gages; bushings; spindles; mandrels; seaming rolls; narrow strip or foil rolls; bending, drawing, cupping, and stamping dies; deep-drawing and forming operations; and other uses requiring high resistance to wear and abrasion.

Black Giant does not replace the standard oil-hardening tool steel (Bethlehem's BTR). It will, however, definitely complement the use of BTR in such special applications as those listed above.

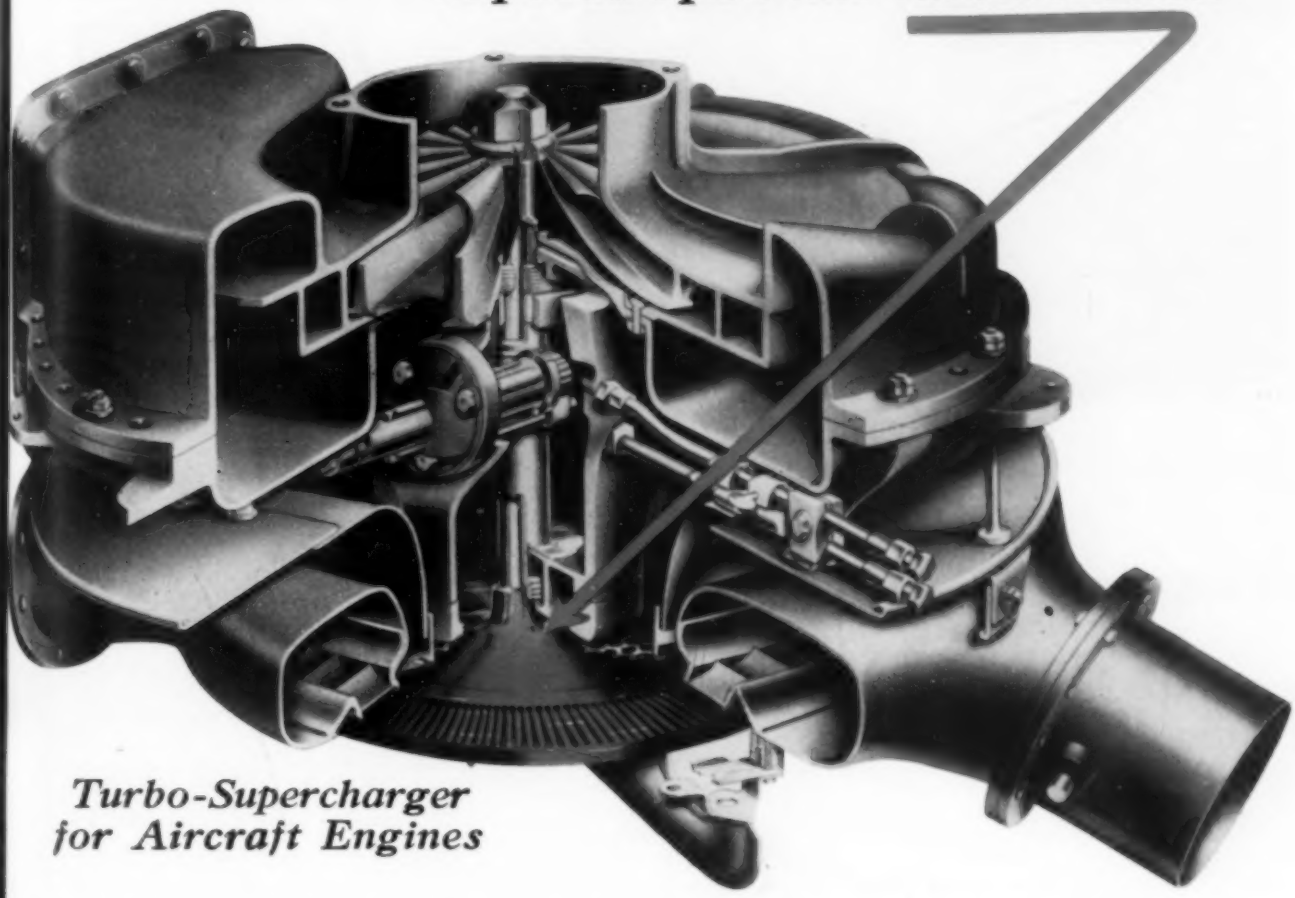
BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY
Bethlehem, Pa.

meet

SUPER-STEEL

The steel able to resist the destructive forces imposed upon this turbine wheel



Turbo-Supercharger for Aircraft Engines

Super-Steel is the name of the new stainless steel created and developed by The Timken Roller Bearing Company. Super-Steel was first used for turbine wheels in the Turbo-Supercharger, the ingenious device developed by the General Electric Company to enable our war planes to fly at unprecedented heights. It is a steel able to withstand the terrific centrifugal force developed by the turbine wheel as it is driven madly 30,000 r.p.m. by red hot exhaust gases at 1700°F. A combination of forces so great that they would cause ordinary steels to disintegrate.

Super-Steel has high creep strength, excellent weldability, can be forged or machined and offers stubborn resistance to scale and corrosion at operating conditions. An imposing list of qualities that not only met the grueling demands of turbine wheels but enabled them to be produced on a mass production basis. Super-Steel promises to aid the development of many products.

The imagination and facilities that developed Super-Steel are at your disposal in selecting a steel for your own products. We invite you to use them. Steel and Tube Division, The Timken Roller Bearing Company, Canton 6, Ohio.

TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

STAINLESS STEELS

"ROCKWELL"
Superficial
HARDNESS TESTER

The use of the "Superficial" type of the "ROCKWELL" Hardness Tester is rapidly increasing

Many important plants have greatly increased their use of the Superficial type of "ROCKWELL" Hardness Tester. This is because its light loads and more sensitive depth measuring system permits equally accurate testing but bases its readings on material nearer to the surface. Where steel must sustain wear the condition of it near the surface becomes of prime importance.

Testing with the "ROCKWELL" Superficial Testers substantially reduces the amount of material to be ground away in removing the minute impression, if the surface happens to be one where no identation mark is permissible.

Increased use of processes such as induction heating and nitriding to produce shallow cases, require the use of the "ROCKWELL" Superficial Hardness Tester without exception.

There are now over 5,000 "Superficial" machines in use and they are just as durable and just as quick and easy to use as the regular "ROCKWELL" Tester

WILSON
MECHANICAL INSTRUMENT CO., INC.
367 Concord Avenue, New York 54

An Associate Company of
American Chain & Cable

Keep that pencil sharp with FIRTHITE

Here's Why!

During the war it was a matter of *production speed* . . . and carbide cutting tools were the answer.

Today it's a matter also of keeping operating costs down. High production, yes . . . but at costs that meet or beat competition. Again Firthite sintered carbide tools will help you keep red ink out of your records, while turning out a better, more salable product.

if you have a tool or die problem

Call

Firth-Sterling
STEEL COMPANY

McKEESPORT, PA. · NEW YORK · HARTFORD · PHILADELPHIA · PITTSBURGH · CLEVELAND · DAYTON · DETROIT · CHICAGO · LOS ANGELES

BOSTON

New England Metallurgical Corp.
9 ALGER STREET
SOUTH BOSTON 3313

CINCINNATI

The Queen City Steel Treating Co.
2978 SPRING GROVE AVE.
KIRBY 6300

CLEVELAND

The Lakeside Steel Improvement Co.
5418 LAKESIDE AVE.
HENDERSON 9100

DETROIT

Commercial Steel Treating Corp.
6100 TIREMAN AVE.
TYLER 6-6086

Commonwealth Industries
5922 COMMONWEALTH AVE.
MADISON 0573

Starr Heat Treating Company
10420 HARPER AVE.
PLAZA 8312

ELIZABETH, N.J.

American Metal Treatment Co.
ELIZABETH 2-2121

INDIANAPOLIS

Metallurgical Service Company
1020 E. MICHIGAN ST.
CHERRY 5203

LOUISVILLE

Louisville Metal Treating Service
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B-M Heat Treating Co.
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SAGAMORE 3027—PARK 2258

PITTSBURGH

Duff-Norton Manufacturing Co.
P.O. Box 1889, LINDEN 1156

Pittsburgh Commercial Heat Treating Co.
49th St. & A.V.R.R.
SCHENLEY 6277

WORCESTER, MASS.

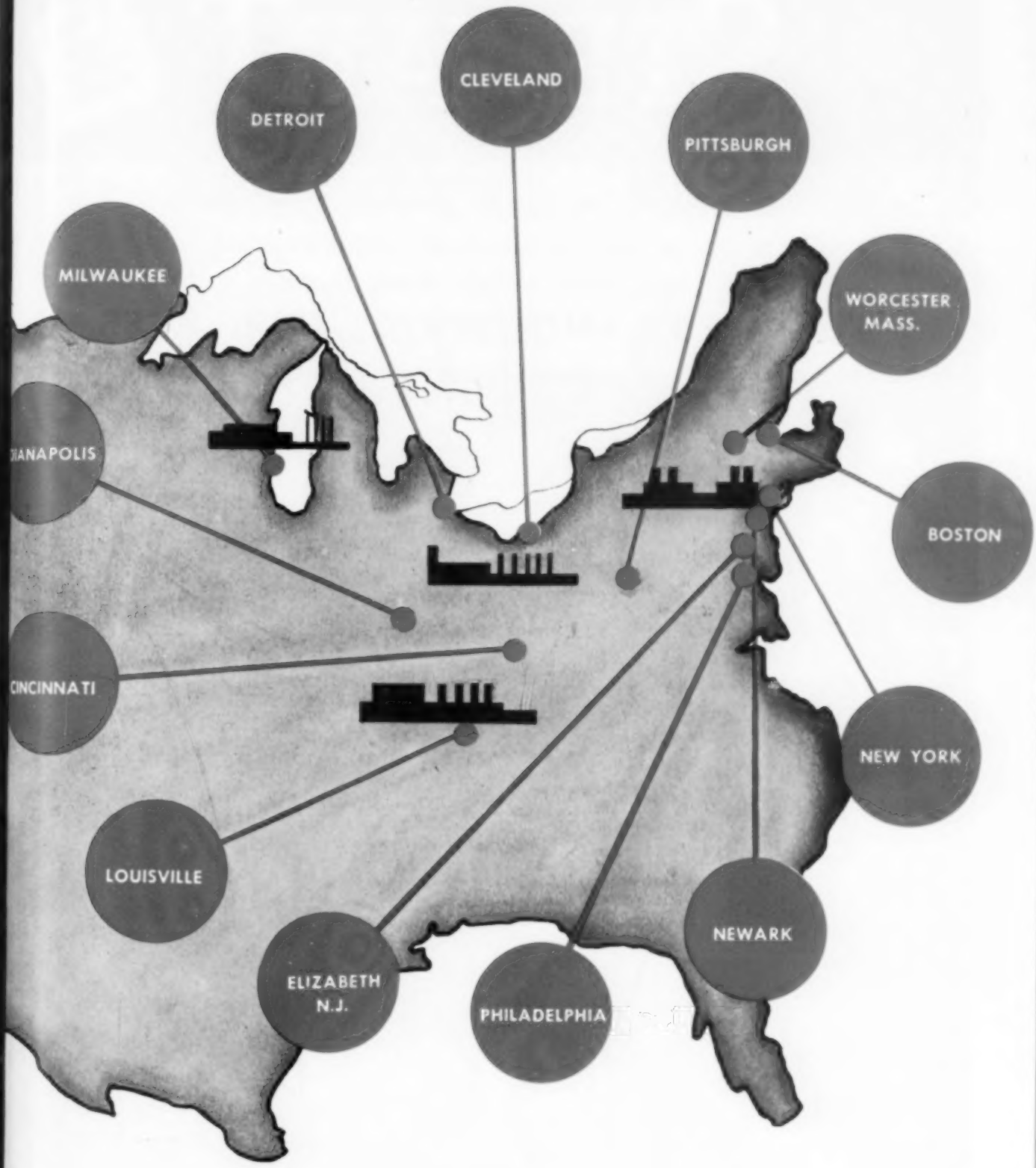
Greenman Steel Treating Co.
284 GROVE STREET
WORCESTER 4-1725

18 COMMERCIAL HEAT TREATING SPECIALISTS STRATEGICALLY LOCATED TO PROFITABLY SERVE AMERICA'S GREATEST INDUSTRIAL AREA

The cities and their trading areas listed in the red circles on the opposite page are a fairly representative group of some of America's highly industrialized localities. In all of those listed there is at least one, and in some cases two or more, commercial Heat Treating Plants who specialize in the treatment for improvement of metals. They have been the pioneers of the industry. Specialists always, they have kept pace with every advance . . . adding to their facilities and "know-how" to meet ever-increasing requirements for higher output and maximum quality.

If you are in or near these cities, it will pay you to tie these Heat Treating Specialists to your production line. Their modern equipment and advanced processing methods can save you many production dollars.

For prompt, profitable service in Annealing, Carburizing, Cyaniding, Hardening, Nitriding, Normalizing, Straightening, Stress Relieving or Tempering of *one piece or thousands*, call in a Heat-Treating Specialist. One of them listed at left, will be glad to assist you in your planning without obligation. Call on him.


CLEVELAND
DETROIT
PITTSBURGH
MILWAUKEE
WORCESTER
MASS.
BOSTON
CINCINNATI
NEW YORK
LOUISVILLE
NEWARK
ELIZABETH
N.J.
PHILADELPHIA

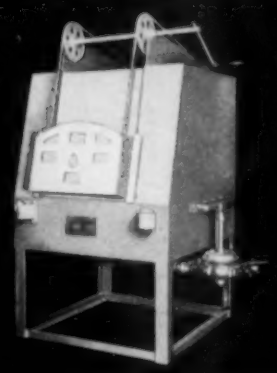
STEWART

THE BEST INDUSTRIAL FURNACES MADE

A TYPE FOR EVERY NEED

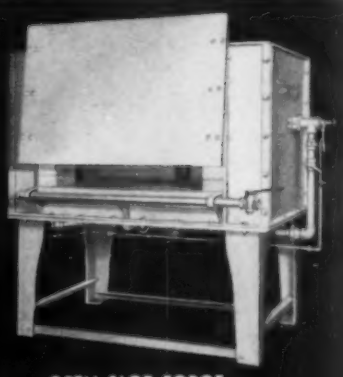
In addition to large units designed to meet specific production requirements, STEWART also builds these famous

STANDARD INDUSTRIAL FURNACES



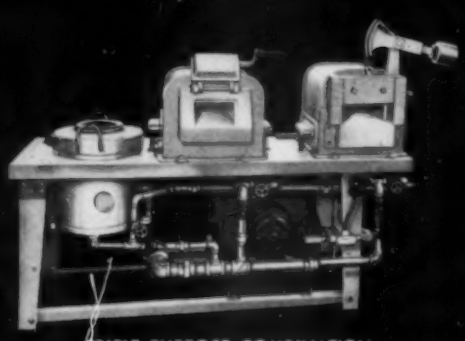
SEMI-MUFFLE OVEN FURNACE

ROUND POT FURNACE

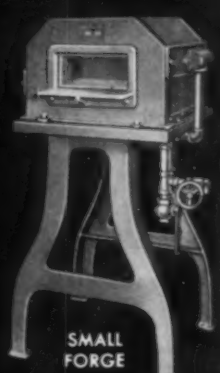


OPEN SLOT FORGE

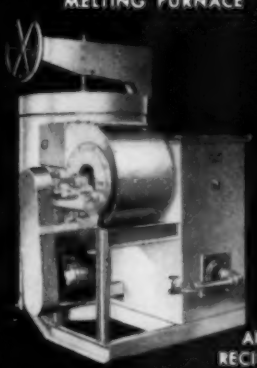
STATIONARY METAL MELTING FURNACE



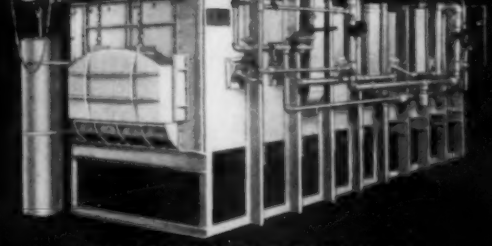
TRIPLE PURPOSE COMBINATION



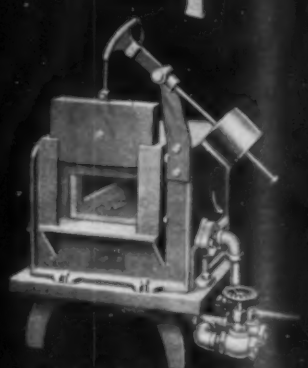
SMALL FORGE



AIR DRAW RECIRCULATING FURNACE



HEAVY PORTABLE OVEN FURNACE



BENCH OVEN FURNACE

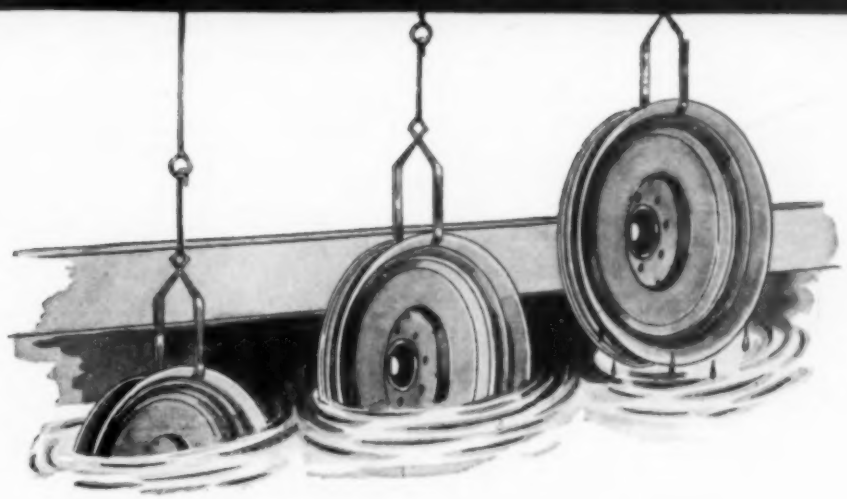
A letter, wire or 'phone call will promptly bring you information and details on STEWART Furnaces. Or, if you prefer, a STEWART engineer will be glad to call and discuss your heat-treating problems with you.

STEWART INDUSTRIAL FURNACE DIVISION OF CHICAGO FLEXIBLE SHAFT COMPANY

Main Office: 5600 W. Roosevelt Road, Chicago 50, Ill.— *Canada Factory:* (FLEXIBLE SHAFT CO., LTD.) 321 Weston Rd., So., Toronto

IRIDITE

PERMITS USE OF ZINC PLATE IN PLACE OF MORE COSTLY MATERIALS



NEW QUICK-DIP PROCESS, ALSO CURBS CORROSION OF GALVANIZING OR CADMIUM

3 WAYS TO BUILD PROFITS WITH IRIDITE

1 **As a final finish:** Iridite is available in a variety of attractive colors.

2 **As a paint base:** Iridite holds paint firmly, even on die cast or newly galvanized surfaces.

3 **To reduce costs:** Consider using galvanized metal, plus Iridite, in place of more expensive materials.

Here's how to use zinc plate in place of more expensive materials. Here's how to curb corrosion on galvanizing, cadmium plate or zinc die-castings. Use Iridite—as a colorful final finish or as a firm paint base! Corrosion-resistant Iridite goes on with a quick dip of 15 to 60 seconds, dries in a few seconds, dries even faster with a hot water rinse, permits immediate handling or shipping. Thus Iridite maintains automatic machine cycles, speeds production, saves time and money.

WIDELY USED

Meeting Army and Navy specifications, Iridite is used on military or civilian products of such manufacturers as Western Electric, Martin Aircraft, Woodstock Typewriters, Sparton, Lockheed and many others. New fields for Iridite are constantly being opened.

SEND FOR TEST PANEL

Send for free test panel, half of it protected by Iridite, and prove for yourself how Iridite balks corrosion . . . how the Iridite treatment does not alter dimensions of finely machined parts . . . how Iridited parts may be cold-worked without flaking, chipping or peeling. Find out now whether Iridite can cut costs or speed production for you. Write for free test panel—today! Address: Rheem Research Products, Inc., 14412 Standard Oil Bldg., St. Paul and Franklin Sts., Baltimore 2, Maryland.

Test Iridite for yourself. Send coupon for this test panel.

RHEEM RESEARCH PRODUCTS, INC.

IRIDITE

Standard Oil Bldg., Baltimore 2, Md.

Reg. U. S. Pat. Off.

RHEEM RESEARCH PRODUCTS, INC.
14412 Standard Oil Building
Baltimore 2, Maryland

Gentlemen: Please send me a free panel of Iridite-treated zinc plate for laboratory testing and full information and operating details.

Name.....

Company.....

Address.....

VANCORAM BRAND

Products for the Iron and Steel Industries

PRODUCT	NOMINAL COMPOSITION	APPLICATIONS
ALSIFER	Aluminum . . . . . 20% Silicon . . . . . 40% Iron 40%	Used principally as a steel deoxidizer and for grain size control.
FERRO CHROMIUM High Carbon Grade	Chromium . . . 66-70% Carbon 4-6%	For wrought constructional steels and steel and iron castings.
Iron Foundry Grade	Chromium . . . 62-66% Carbon . . . . . 4-6% Silicon 6-9%	For alloyed cast irons. Readily soluble as a ladle addition at the lower temperatures of cast iron.
Low Carbon Grades	Chromium . . . 67-72% Carbon . . 06%, .10%, .15%, .20%, .50%, 1.00% and 2.00% max.	For low carbon chromium steels, especially those with high chromium content, such as stainless and heat-resistant types.
FERRO SILICON 25-30% Grade	Silicon 25-30%	Deoxidizer for open hearth steels; also for high silicon, corrosion-resistant iron castings.
50% Grade	Silicon 47-52%	Used as a deoxidizer and for the addition of silicon to high silicon steels, for springs, electrical sheets, etc. Pulverized form used as ladle addition to cast irons for silicon content and graphitization control.
75% Grade	Silicon 74-79%	For high content silicon steels, such as spring steels, sheets and forgings of high magnetic qualities for electrical apparatus.
High Silicon Grades 80-85% 85-90% 90-95%	 Silicon . . . . 80-84.9% Silicon . . . . 85-89.9% Silicon 90-95%	For high content silicon steels where small ladle additions are used for required silicon content. Also for manufacture of hydrogen by reaction with caustic soda and production of magnesium by the Pidgeon process.
FERRO TITANIUM High Carbon Grade	Titanium . . . . 15-18% Carbon 6-8%	Final ladle addition to control "rimming" action and to clean effervescing steel. Final deoxidizer and scavenger for steel castings and fully killed ingot steels.
Medium Carbon Grade	Titanium . . . . 17-21% Carbon 3-4.50%	Often preferred to the High Carbon Grade as a final ladle addition to very low carbon rimming or effervescing steels.
Low Carbon Grades 20-25% Ti Grade	Titanium . . . . 20-25% Carbon . . Max. 0.10% Silicon . . . . Max. 4% Aluminum Max. 3.50%	As a carbide stabilizer in high chromium corrosion resistant steels of extremely low aluminum content. Deoxidizer for some casting and forging steels.
40% Ti Grade	Titanium . . . . 38-43% Carbon . . Max. 0.10% Silicon . . . . Max. 4% Aluminum . . Max. 8%	As a carbide stabilizer in high chromium corrosion resistant steels, where smaller ladle additions are desired and extremely low aluminum content is not essential.
VANADIUM METAL 90% Grade	Vanadium . . . . 91.15% Aluminum . . . . 3.87% Silicon . . . . . 0.50% Carbon 0.17%	For special iron-free (non-ferrous) or low iron alloys or low impurity ferrous alloys.
95% Grade	Vanadium . . . . 95.18% Aluminum . . . . 2.00% Silicon . . . . . 0.27% Carbon 0.15%	Principally for research on the properties of pure alloys.

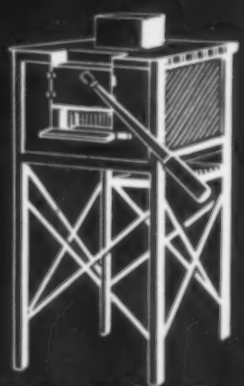
PRODUCT	NOMINAL COMPOSITION	APPLICATIONS
FERRO VANADIUM Grade "A" (Open Hearth)	Vanadium . . . 35-40% Silicon . . . . Max. 12% Carbon . . Max. 3.50%	For low percentage vanadium content of rolled, forged or cast constructional steels. Also used in vanadium cast irons.
Grade "B" (Crucible)	Vanadium . . . 35-45% Silicon . . Max. 3.50% Carbon . . Max. 0.50%	For tool steels and special steels containing high percentages of vanadium, in which required limits for carbon and silicon are narrow.
Grade "C" (Primos)	Vanadium . . . 35-45% Silicon . . Max. 1.25% Carbon . . Max. 0.20%	For tool steels and special steels requiring high percentages of vanadium and exceptionally low carbon and silicon content.
Special Grades	Vanadium . . . 50-55% 60-65% 70-80% Silicon . . . . . Low Carbon . . . . . Low	For special applications and uses requiring large vanadium additions.
VANADIUM PENTOXIDE Technical Grade Fused Form	V_2O_5 . . . . 90%	A source of vanadium in basic electric furnace steels. A base for numerous chemical compounds.
Technical Grade Air Dried Form	V_2O_5 . . . . . 85%	A base for preparation of numerous chemical compounds, such as catalysts, etc.
GRAINAL ALLOYS Vanadium Grainal No. 1	Vanadium . . . . 25.00% Aluminum . . . . 10.00% Titanium . . . . . 15.00% Boron 0.20%	Practical and economical intensifiers for controlling and increasing the capacity of steels to harden, and for improving other important engineering and physical properties.
Vanadium Grainal No. 6	Vanadium . . . . 13.00% Aluminum . . . . 12.00% Titanium . . . . 20.00% Boron 0.20%	See above.
Grainal No. 79	Aluminum . . . . 13.00% Titanium . . . . 20.00% Zirconium . . . . 4.00% Manganese . . . 8.00% Boron . . . . . 0.50% Silicon 5.00%	See above.
GRAPHIDOX No. 4	Silicon . . . . . 45-50% Titanium . . . . . 9-11% Calcium 5-8%	New alloy for the graphitization of iron; ladle treatment insures iron with normal graphite, free from dendritic structure; reduces chill; efficient inoculant in the production of high strength irons.
V-FOUNDRY ALLOYS V-5 Grade	Chromium . . . . 38-42% Silicon . . . . . 14-16% Manganese 8-11%	Used in cast irons as a ladle addition. Reduces chill, promotes uniformity of structure, increases strength and hardness.
V-7 Grade	Chromium . . . . 28-32% Silicon . . . . . 15-21% Manganese . . . 14-16%	See above.
BRIQUETTES Ferro Chromium	Hexagonal in shape. Weighs approximately 3⅜ pounds and contains 2 pounds of chromium.	A practical and convenient form for adding ferro alloys to the cupola.
Ferro Silicon	Two sizes available, both cylindrical in form, one containing 1 pound of silicon; the other 2 pounds of silicon.	See above.

VANADIUM CORPORATION OF AMERICA

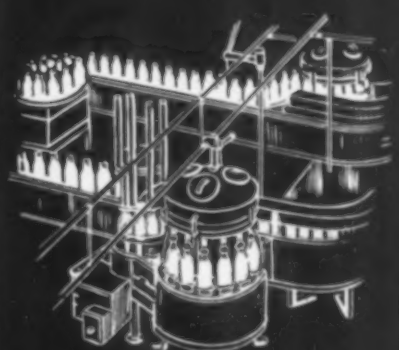
420 LEXINGTON AVENUE, NEW YORK 17, N. Y. · DETROIT · CHICAGO · CLEVELAND · PITTSBURGH

ANGLES OF JOSLYN STAINLESS STEEL

For CORROSION RESISTANCE
Maximum resistance to atmosphere, acids and other corrosive elements.



For HEAT RESISTANCE . . . .
Greater scale resistance and durability under continuous exposure to heat.



For CLEANLINESS . . . . . .
"Stainless" quality permits easy cleaning of facilities for handling foods and beverages.

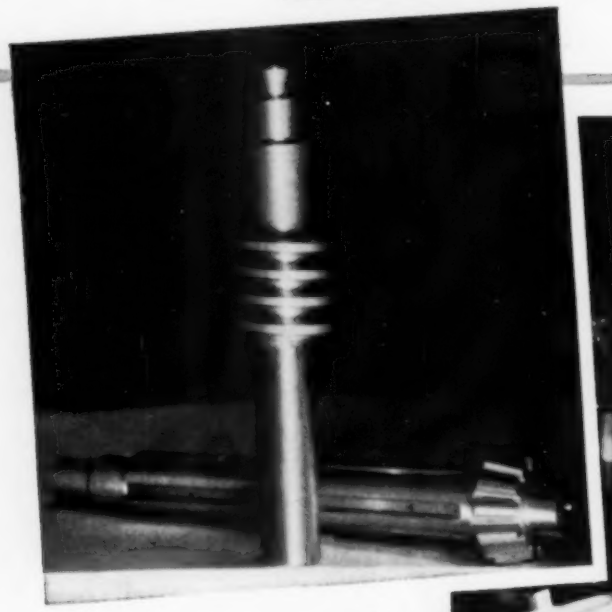
For STRENGTH . . . . . .
Durable under stress and strain well beyond normal requirements.

Joslyn Stainless Steels

JOSLYN MFG. AND SUPPLY CO., FT. WAYNE 6, IND.

BILLETS · FORGING BARS · HOT ROLLED AND · COLD FINISHED BARS

FOR THE *Special* JOBS OF INDUSTRY



FOR PARTS that must have high surface hardness and wear resistance, that must retain hardness at elevated temperatures, that require high resistance to fatigue, a complete line of Nitralloy Steels (special U·S·S Carilloy Alloy Steels most suitable for case hardening by nitriding) is available. Our metallurgists will gladly discuss their application in terms of your requirements.

THE TOUGHNESS of alloy steel makes it the right material for the construction of forming machinery. The proper steel for each application can be designed to hold a true shape for thousands of operations and to resist the deteriorating effects of impact and abrasion.

OF THE TESTS which attempt to duplicate service conditions o high temperature operation, the long-time "creep" test is th most significant. The value of research work such as this i demonstrated in a striking way by the increased fuel economy being reported by central generating stations which, becaus of the stronger alloy steels now available for high temperatur service, are able to operate safely at higher temperatures an pressures.

USS STEEL
UNITED STATES STEEL

...Electric Furnace Steels

★ **Special Heat-Resisting Steels**

★ **Aircraft Quality Alloy Steels**

★ **Bearing Steels . . . Nitralloy Steels**

IN ALL GRADES, IN ALL FINISHES, AND IN THE WIDEST RANGE OF SIZES

TO meet your present and future needs for these *quality* alloy steels, two completely integrated Electric Steel plants, one at Chicago and one at Pittsburgh, are ready to serve you.

Unequalled facilities for on-the-spot rolling, finishing and heat treating permit us to furnish electric furnace alloy blooms, billets and bars, slabs, plates, sheet and strip, as well as standard and special sections. Wide flexibility in furnace capacity makes it possible to handle, promptly, small orders as well as large.

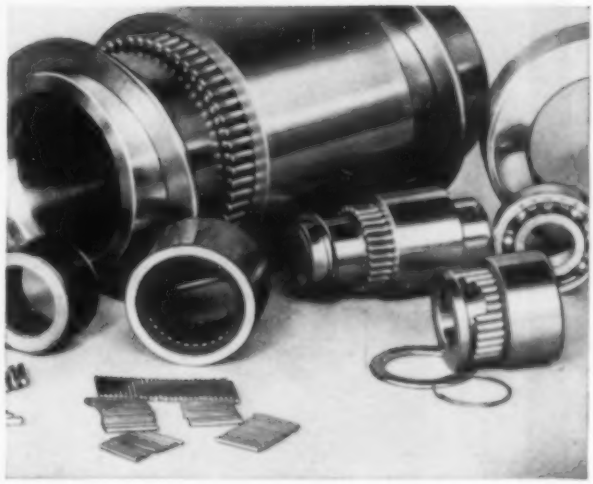
In these plants the fine art of steel making has been brought to new peaks of perfection. For not only are the men who control and operate them of thoroughly seasoned skill and experience, but they have at their service electric steel production equipment as fine, as complete and as modern as anywhere available.

The steels they produce reflect these facts. The close controls possible in the electric furnace assure consistently uniform response to heat treatment and to forging, machining and welding processes that can be readily translated into better performance of your end product.

CARNEGIE-ILLINOIS STEEL CORPORATION

Pittsburgh and Chicago

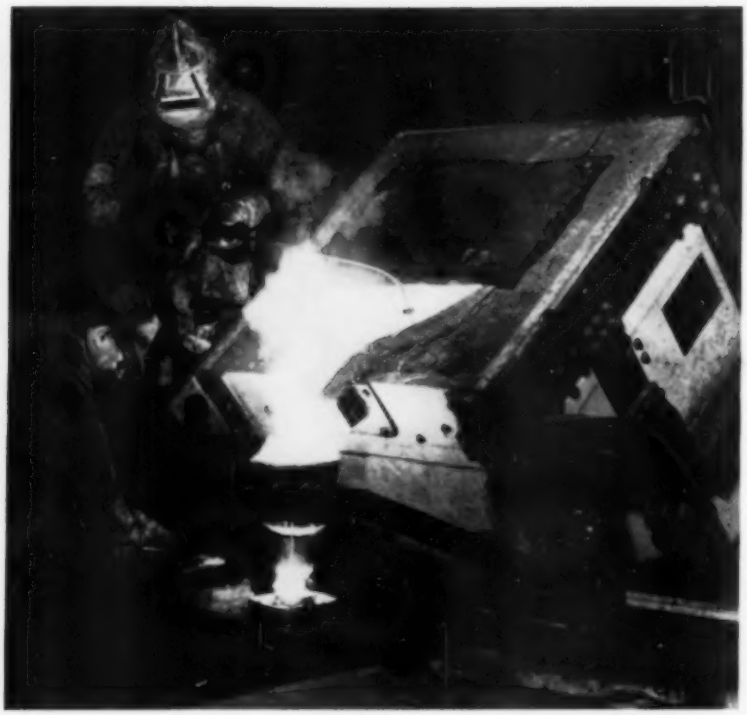
Columbia Steel Company, San Francisco, *Pacific Coast Distributors*
United States Steel Export Company, New York



WHERE PRECISION is a "must," as with bearings and gears, the unvarying uniformity of U·S·S Carilloy Alloy Steels helps designers meet difficult performance standards. These steels are easy to forge, easy to machine, and respond consistently to annealing and heat treatment.

FRAMES, struts and actuating arms of this retractable landing gear are made almost entirely of special Aircraft Quality alloy steel forgings, that soak up tons of shock without weakening or giving way. On larger planes, hydraulic cylinders are shaped and welded from alloy steel plate.

UNITED STATES STEEL



For pit furnaces, direct arc type rocking furnaces, for induction and high frequency furnaces, for all non-ferrous metal-melting applications, there is a correct Norton refractory cement or prefired shape. Any one of a variety of mixtures is available, employing fused alumina silicon carbide or fused magnesia as the basic constituent—for melting aluminum, copper-alloys and nickel-chromium, nickel-silver, copper-nickel and cadmium bronze alloys.

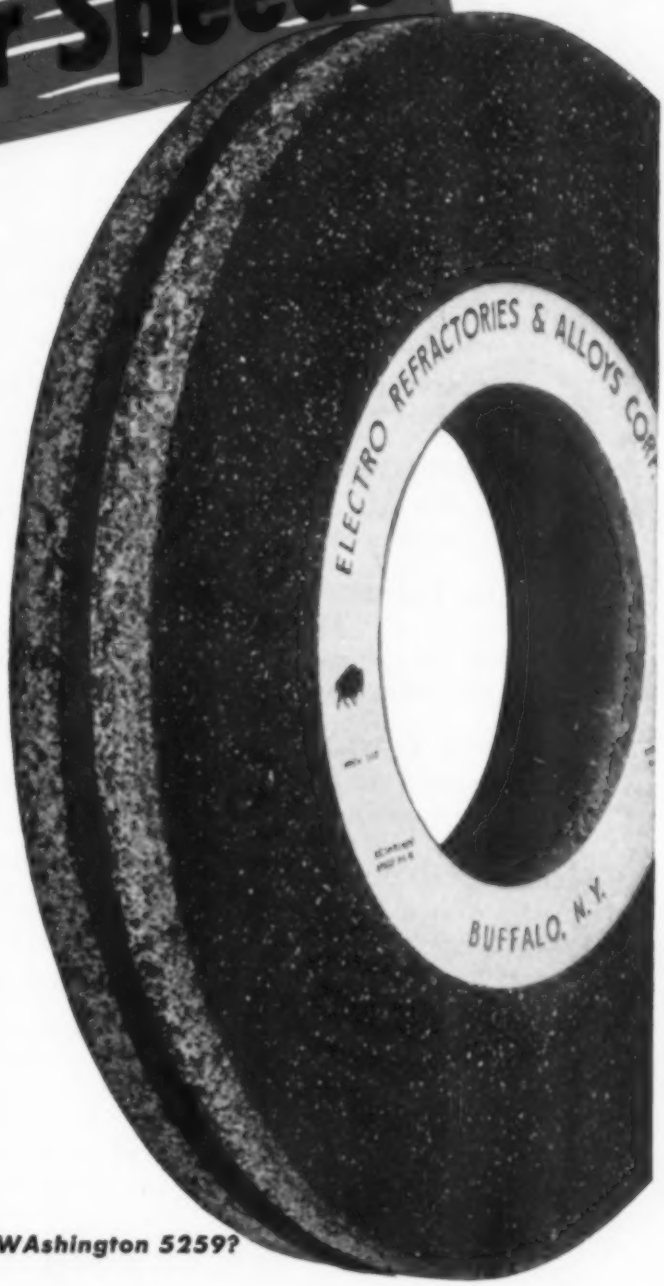
Norton

REFRACTORY CEMENTS

NORTON COMPANY
Worcester 6, Massachusetts

NORTON ABRASIVES

COOLER CUTTING at Higher Speeds



THESE new Electro High-Speed Grinding Wheels afford faster cutting without troublesome heat development whether the grind is for snagging or for fine finishing.

We believe that war demands made it possible for ELECTRO to show cooler cutting at higher speeds, and present high state of perfection will be the basis for further gains. All we ask is opportunity to prove the cooler cutting at higher speeds of our wheels.

Will you wire us?—or phone us at Buffalo, WAshington 5259?

K-310

Electro REFRACTORIES & ALLOYS CORPORATION

Mfrs. of Crucibles • Refractories • Stoppers • Alloys • Grinding Wheels

344 DELAWARE AVENUE BUFFALO 2, NEW YORK

SINCE 1919

Try this Quiz on YOUR METALLURGIST

Q. WHAT IS SULFITE-TREATED STEEL?

A. It's steel which has been mixed with sodium-sulphite while the steel is in the molten state. This is known as the Sulfite Process. It's an exclusive Wisconsin Steel development.

Q. WHAT DOES THE SULFITE PROCESS DO?

A. It cleanses the steel of abrasive oxide inclusions and it adds a small quantity of sulphur to the steel in a widely dispersed state.

Q. WHAT IS THE EFFECT OF THIS PROCESS?

A. The machinability of the steel is tremendously increased. Tool life is greatly extended—often as much as 200%—and production costs are slashed.

Q. DO SULPHUR ADDITIONS EVER HAVE DISADVANTAGES?

A. Yes, but the Sulfite Process is *not* an ordinary sulphur addition. The Sulfite Process has absolutely *no effect* on the surface condition or the physical properties of the steel. An added advantage is the constant uniformity of Sulfite-Treated Steel.

Q. HOW ABOUT STEEL THAT IS HEAT-TREATED?

A. Tests have proved that Sulfite-Treated Steel can be heat-treated and the results will still be the same—far greater machinability.

Q. CAN SULFITE-TREATED STEEL BE APPLIED TO A WIDE RANGE OF PRODUCTS?

A. It is used for everything from crankshafts and axles to wrench sockets and gears. In every application, production costs were cut and a better finished product obtained.

Q. IS IT POSSIBLE TO SULFITE PROCESS ANY STEEL?

A. Any steel can be Sulfite Processed. In every case, beneficial results will be noted. But benefits are most pronounced in steel with 30 carbon or over. It's the latest and most practical way to increase machinability.

Consult the Wisconsin Steel sales and metallurgical staffs about your machining problems. We are confident that Sulfite-Treated Steel can solve them.

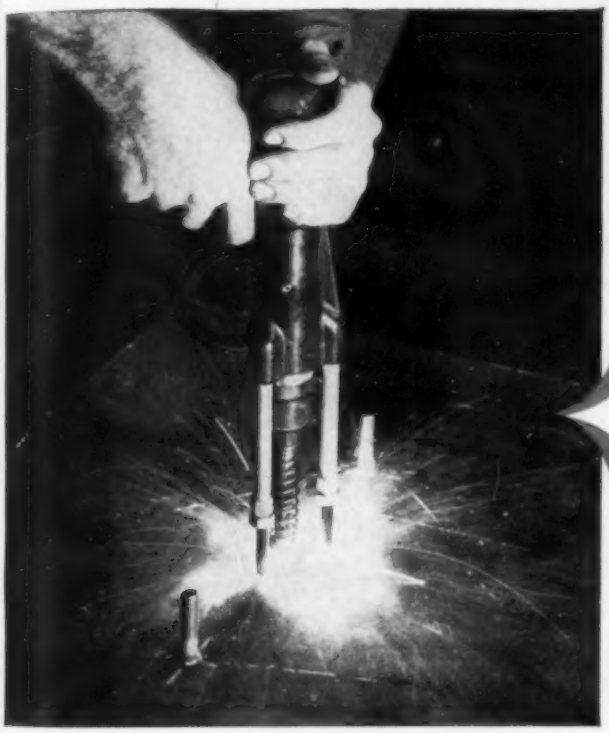
WISCONSIN STEEL COMPANY

(Affiliate of International Harvester Company)

180 North Michigan Avenue — Chicago 1, Illinois

WISCONSIN SULFITE-TREATED **STEEL**

6 ways to fasten metal parts in ½ second with NELSON *automatic* STUD WELDING

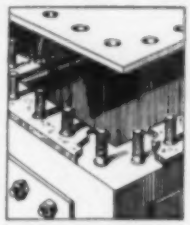


The NELSON Stud Welder is fully portable, works from any standard welding generator, and welds in any position. Studs from ⅛" to ¾" in diameter and up to 8" in length are welded with complete fusion to metal in ½ second.
To speed production, to do a *better* job faster, put this versatile tool on *your* job. The facts are yours for the asking . . .

☛ *WRITE NOW for complete information, or to arrange a demonstration in your own shop at your convenience . . .*

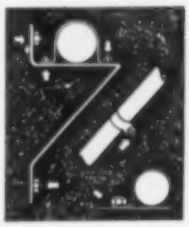
NELSON SALES CORPORATION
LORAIN, OHIO
Representatives and Distributors for
Nelson Specialty Welding Equipment Corp. San Leandro, California
Nelson Stud Welding Corp. Lorain, Ohio

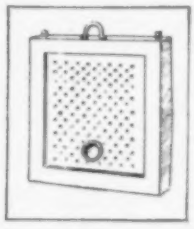
STRAIGHT STUDS



Securing Covers: Covers of all kinds, with or without gaskets, can be secured quickly and easily. Usually the cover itself can be used as a template; studs are welded through the cover holes.

Pipe Hangers and Brackets: There are scores of faster, better ways to secure pipe, tubing or conduit with stud welding. Welds can be made in all positions; welder is completely portable.

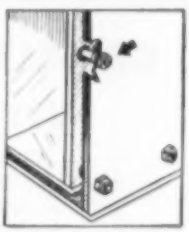


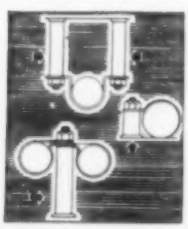


Securing Hearth Door Refractory: Plain studs welded to frame and water tubes securely hold refractory. Method has many practical furnace and firebox uses.

SHOULDER STUDS

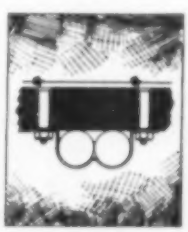
Metal Liners and Jackets: The shoulder stud provides correct spacing between liner and casing or jacket, and no holes pass through the liner which can be left smooth and unblemished.





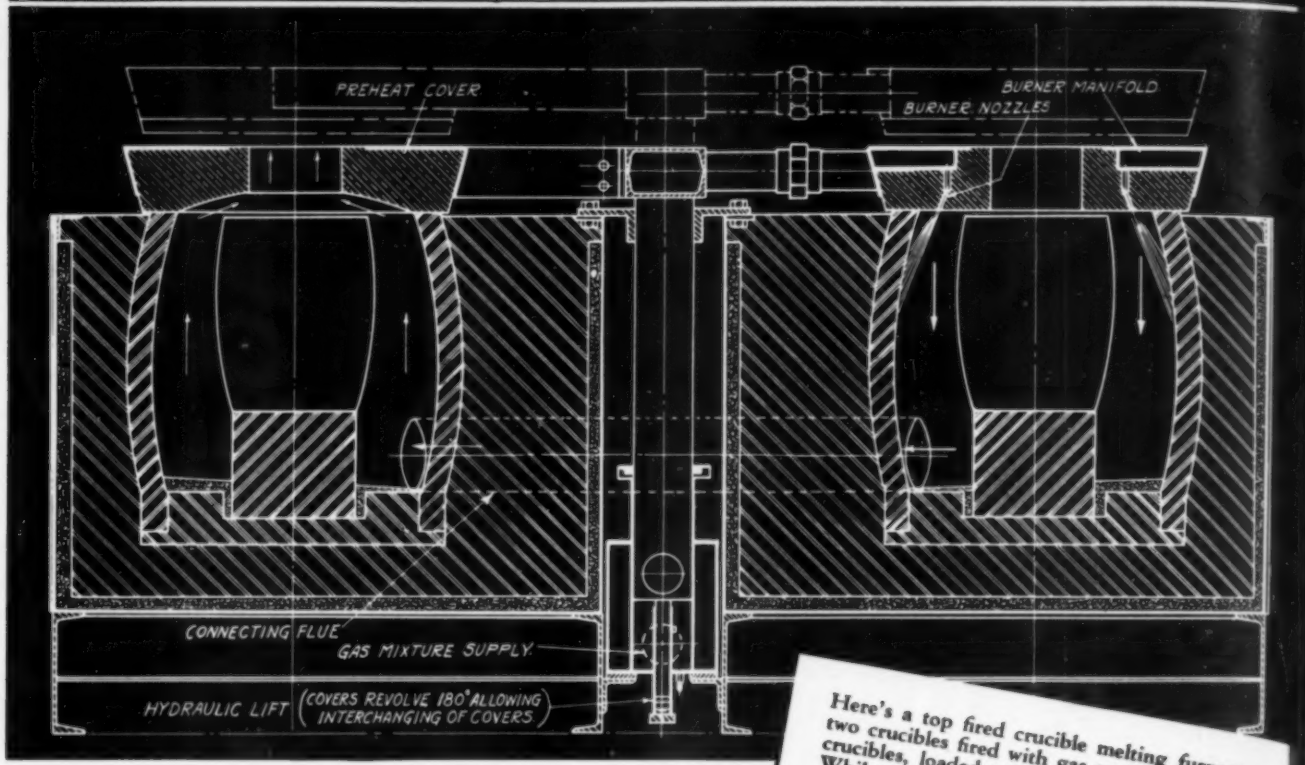
Securing Pipe, Cable and Hose: Shoulder studs provide a fast, convenient method of attaching many types of pipe, conduit, cable, tubing or hose; three typical applications are illustrated at left.

Securing Brackets over Lagging: Brackets for pipe, gauges, etc., may readily be attached through boiler or tank lagging with shoulder studs, which can also be used to secure the outer jacket.



OTHER NELSON FLUX-FILLED STUDS

NEW IT'S DIFFERENT IT'S BETTER NEW



Here's a top fired crucible melting furnace using two crucibles fired with gas or oil in tandem. Two crucibles, loaded at all times, are fired alternately. While the first crucible is heated, the flue gases from it preheat the second crucible. While metal from the first crucible is being poured, a third crucible replaces the removed crucible to receive cold metal. The covers, lifted hydraulically, are interchanged by swinging them 180° permitting the preheated crucible to be direct fired while the cold metal is being preheated in the newly placed crucible. The advantages are so outstanding that no one can afford to use the older type. Section shown here has the stationary type crucibles . . . tilting types are also available.

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5. 50 to 100% longer burner life.
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11. Burners easy to inspect and replace. (Change in 15 minutes)
12. Burners cannot plug. (Burners in top where slag or metal cannot reach them)
13. Pure metal. (Neutral pressure on metal surface allows charcoal or atmosphere to be used)
14. Furnace can be flued through the floor to the outside, eliminating heat and gases in foundry.
15. No leakage of cover. (No flame through or around cover)
16. Quiet operation.
17. Unobstructed flueing. (Flued at bottom and charge does not affect it)
18. Metal is visible at all times and temperature can be taken at any time, without shutting off burners.

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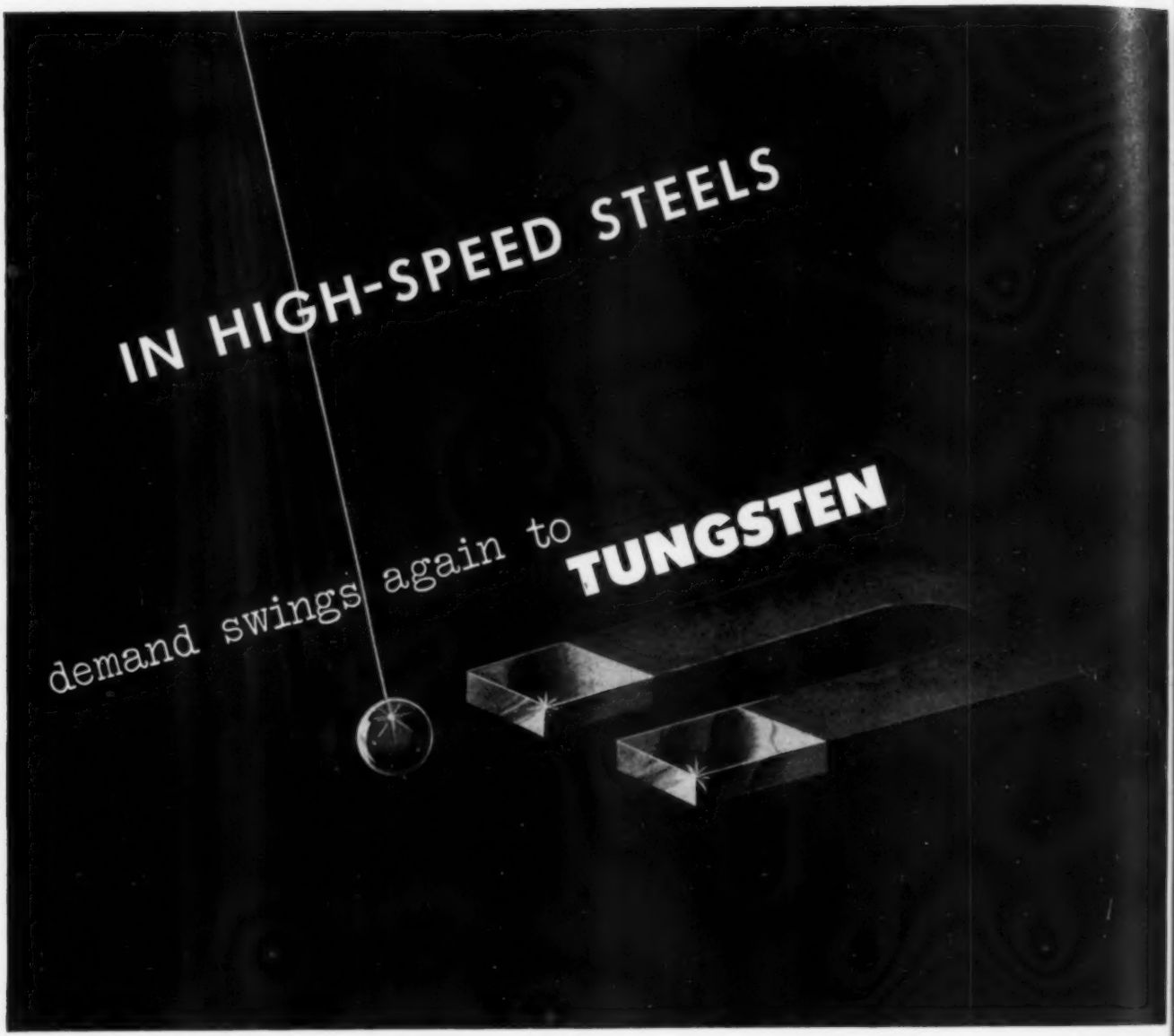

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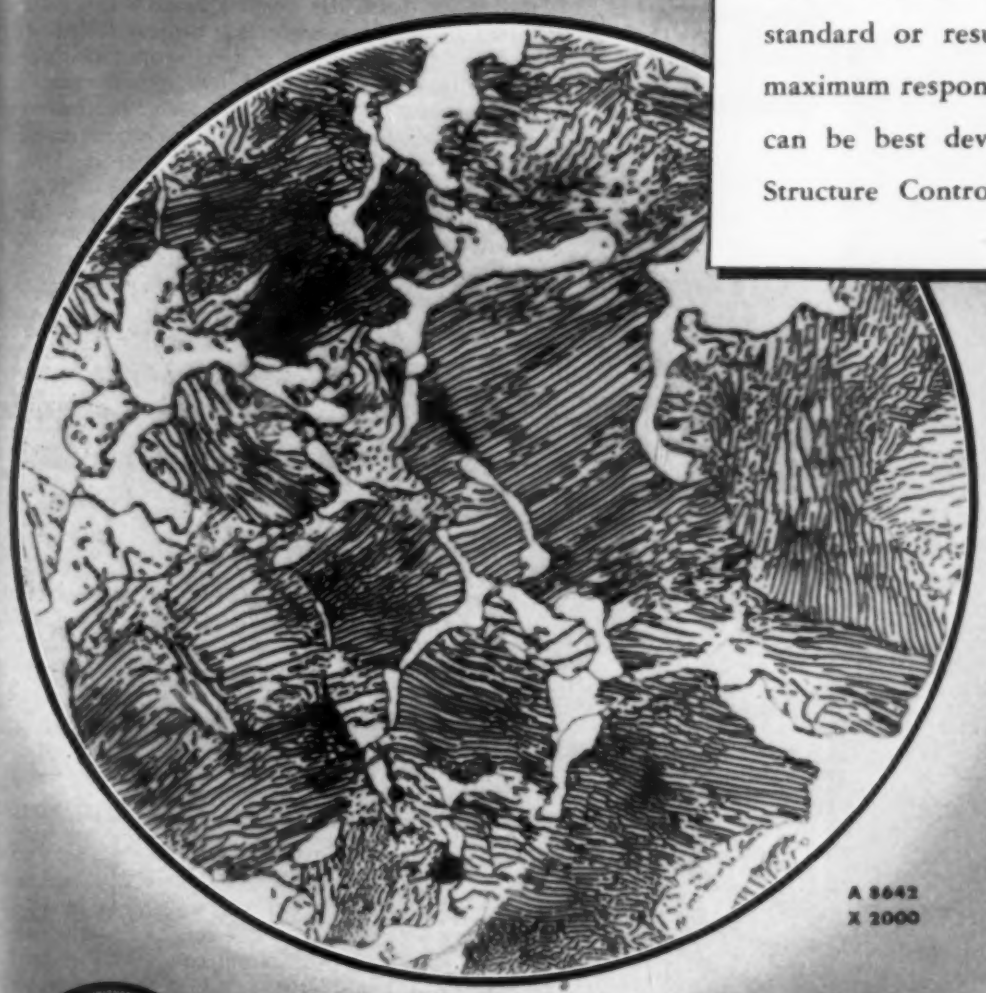

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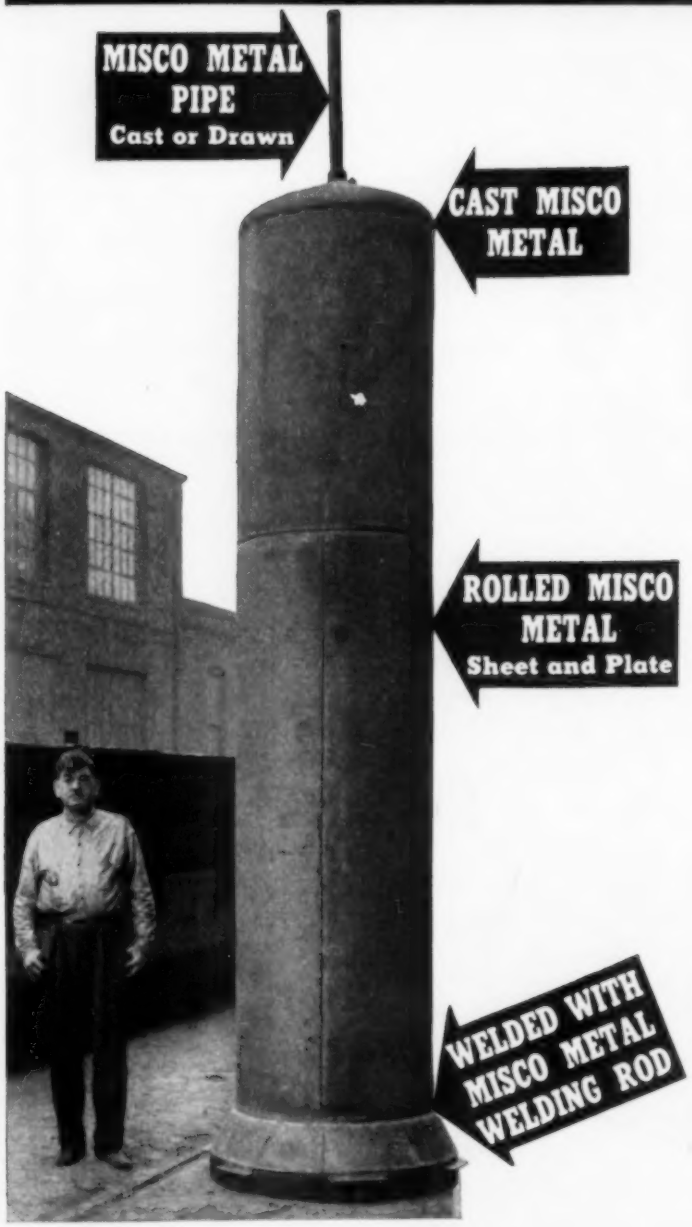

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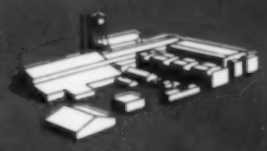

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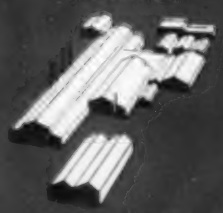

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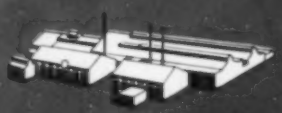

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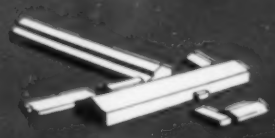

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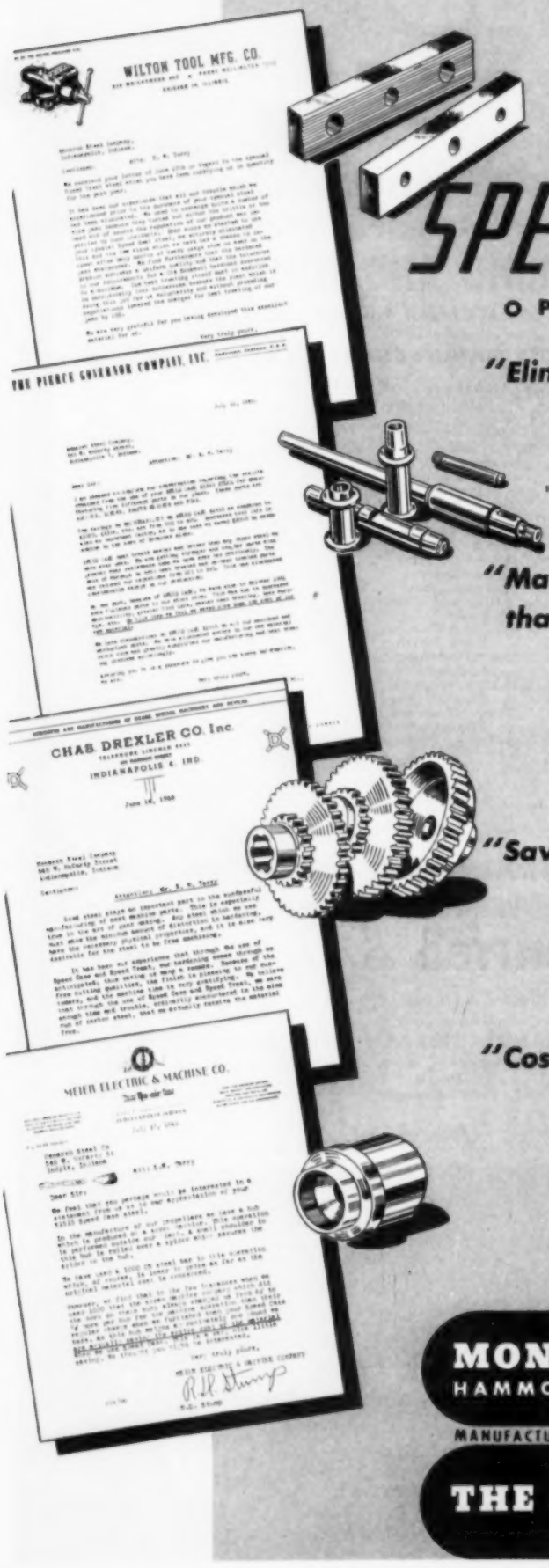

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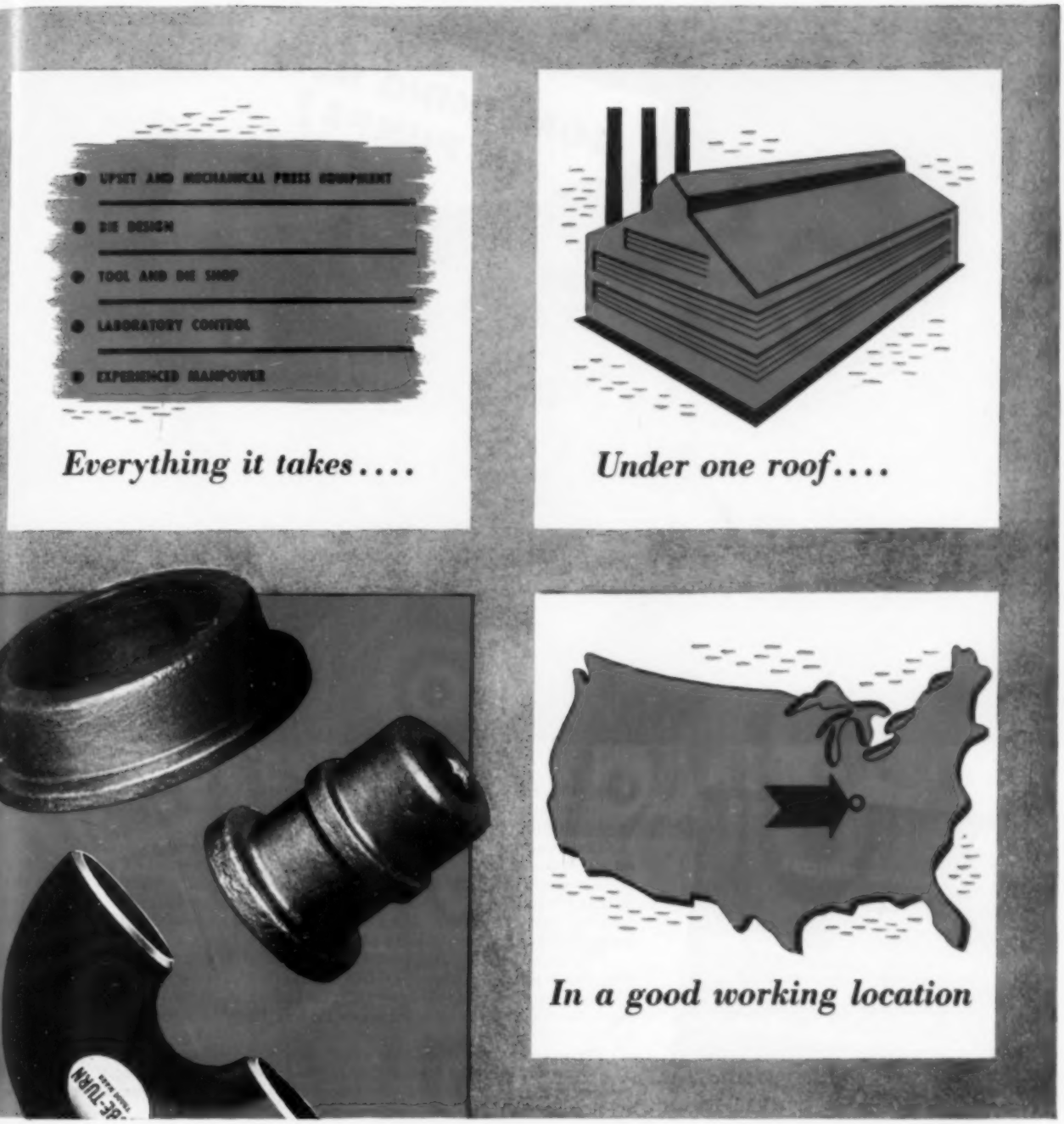

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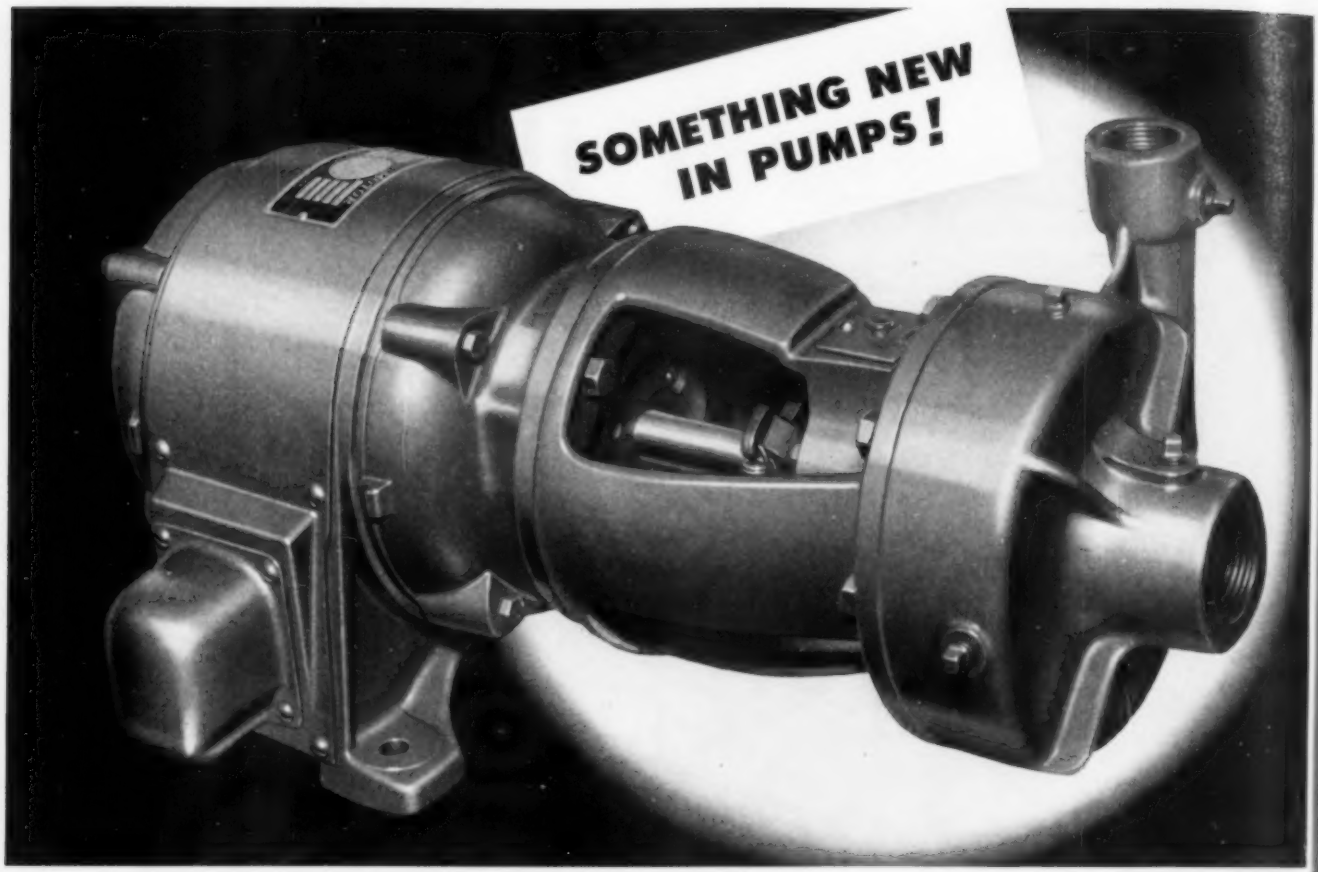

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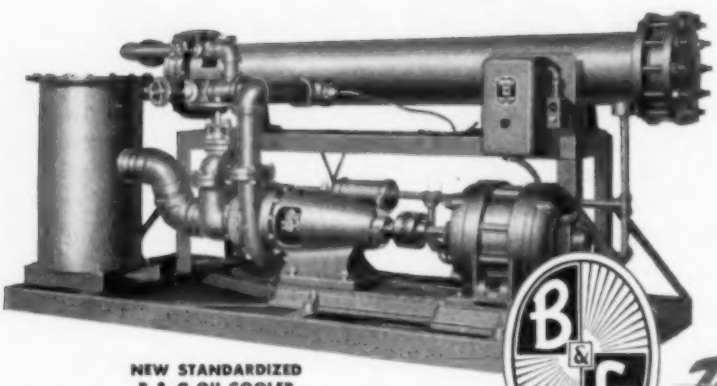

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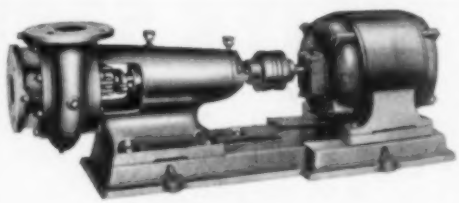

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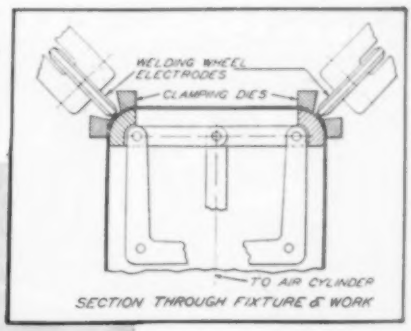
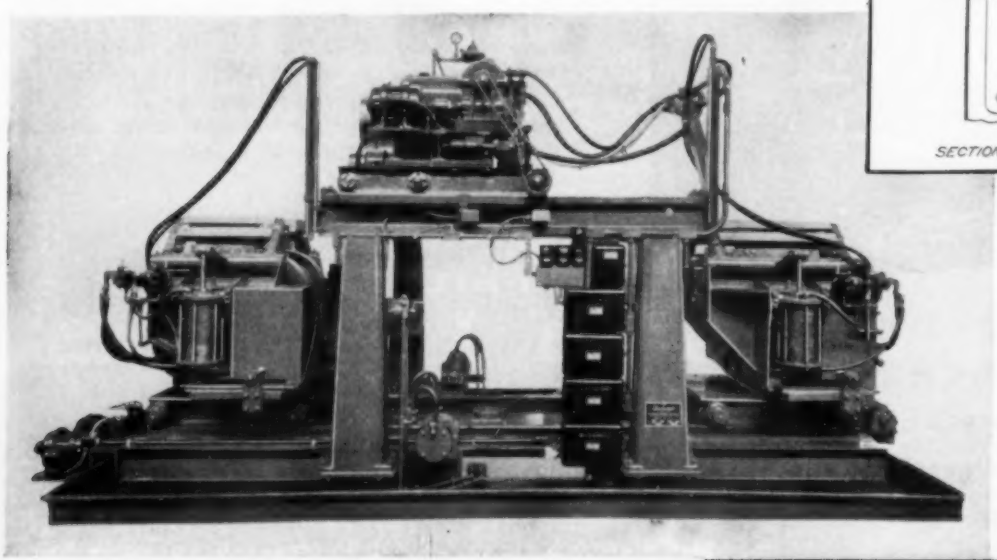
Except for the fact that it is comparatively a modest example, this is typical of direct savings achieved when a product and Federal Resistance Welding are brought together by careful engineering and design. Such records are not limited to any one type of metal working industry. Successful applications cover everything from small parts assembly or joining stainless steel blades to mild steel handles for tools or cutlery, clear through all branches of sheet metal fabrications (including refrigerator liners, casings, grilles and parts) to heavy flash welding of steel ring gear blanks ten or more feet in diameter, with solid cross-sections of eighteen inches.

To find out how Federal Resistance Welding can affect the arithmetic of your particular production problem, send your specifications for applications analysis



SECTION THROUGH FIXTURE & WORK



THIS FEDERAL RESISTANCE SEAM WELDER

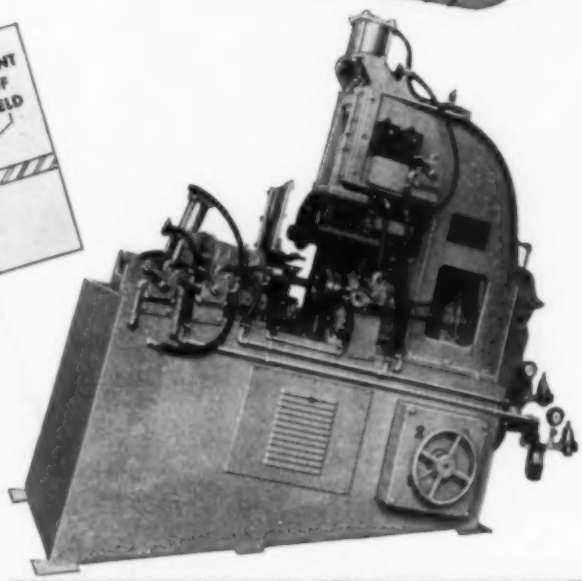
Seam welds multiple, leak-tight joints like this.

INSTALLED BECAUSE IT CUTS COSTS

The Federal

MACHINE AND WELDER CO.

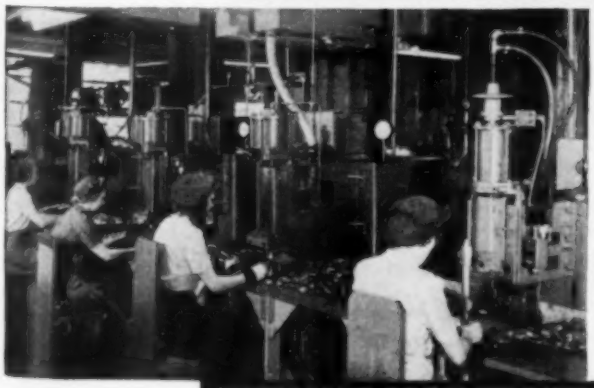
THIS KIND OF



THIS FEDERAL RESISTANCE SEAM WELDER

Seam welds refrigerator casings like this.

INSTALLED BECAUSE IT CUTS COSTS



THESE FEDERAL RESISTANCE WELDERS

All standard models, attain high production in assembling small parts components.

INSTALLED BECAUSE THEY CUT COSTS

238 DANA ST., WARREN, O.

MEMBER RESISTANCE WELDER MANUFACTURERS' ASSOCIATION RWMA

VERSATILE MODERN PRODUCTION TOOLS

NEW HYDRAULIC WELDERS

Two new models of spot and projection welders, hydraulically operated, are described for the first time in detail in Bulletin 4520 issued by The Federal Machine and Welder Company. One type, available in three sizes with 30, 50, or 75 KVA transformers, employs an inverted hydraulic cylinder in which the piston rod is the fixed member mounted on a unique adjustable connection which provides for close timing and quick follow up. A larger model, available in two sizes of 100 and 150 KVA also is described. Complete specifications are listed.

HOUSEWARE PRODUCTION

Anticipated expansion of houseware production points up the advantages of Federal resistance welding for the fast, low cost application of handles to enameling steel or aluminum pots and pans. Press type welders are used, with dies that permit rapid loading, give production of 500 to 800 handles per hour, depending upon type of handle applied. Cost with one manufacturer is one-fifth previous method.

HOW TO MAKE PROJECTIONS

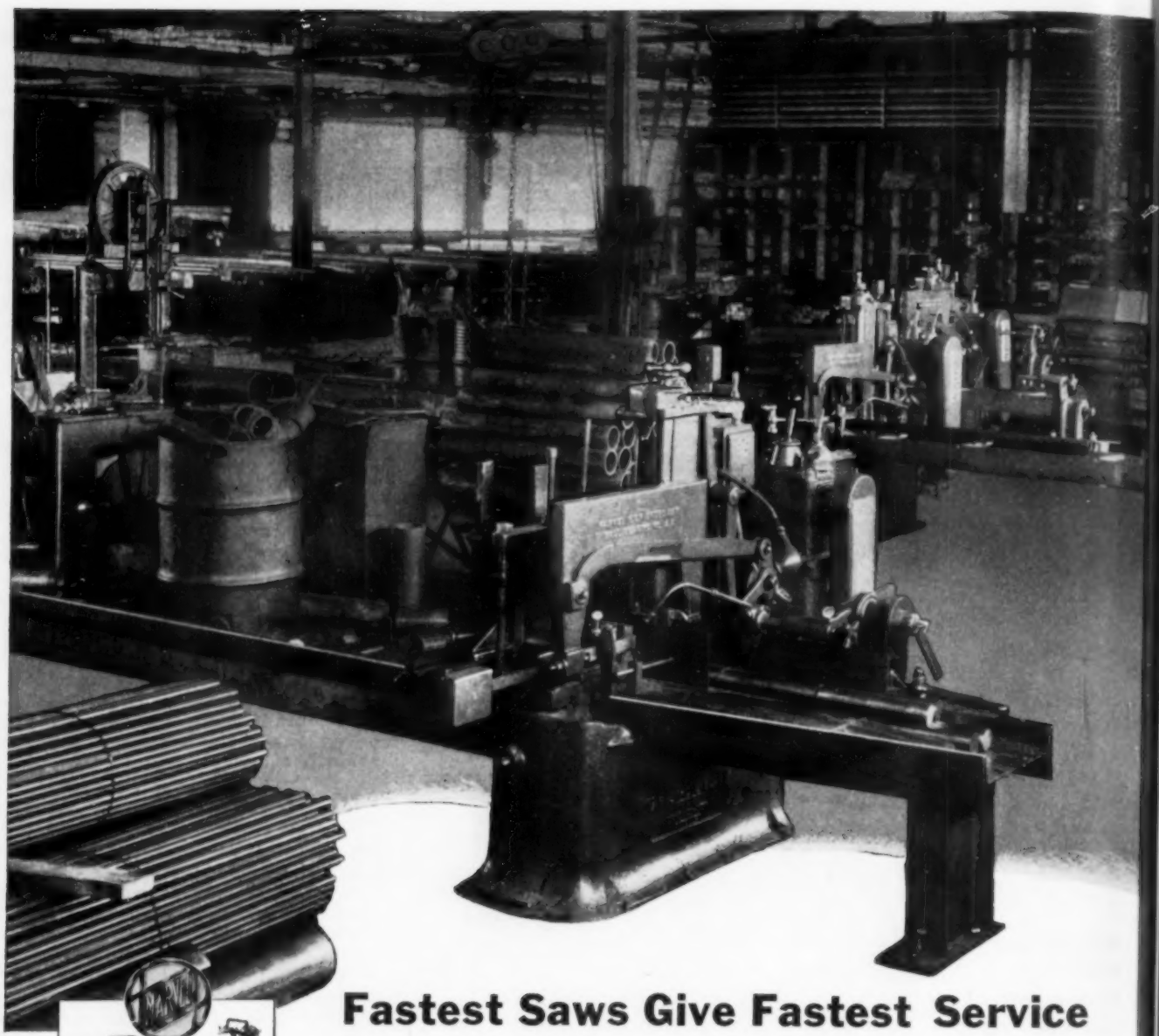
Interesting and useful information on machines and methods for projection resistance welding is included in a new sixteen page booklet just released by The Federal Machine and Welder Company. There are descriptions of various types of projections, tables of proper measurements for projections and complete data on twenty varieties of welders adaptable for either projection of spot welding.

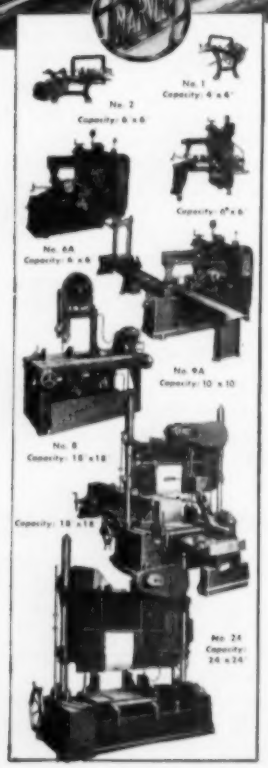
Several interesting special applications are illustrated. These include an eight-station dial-feed fixture for automatic welding of radar tube assemblies at high speed; a dual head for series projection welding; a special fixture for welding aircraft heat exchangers; several air clamping fixtures for quick loading and unloading of work in welding dies; a machine that automatically welds nails to trim moulding.

Special equipment such as rubber heads, air-lock heads and anti-friction slides also are shown. The book is available on request . . . Bulletin 4520.

FOR CONTAINER MAKERS

A special book of particular interest to container manufacturers is in the list of literature available on request at The Federal Machine and Welder Company. Principal theme is description of a complete steel barrel welding plant. Several special machines for resistance welding a variety of metal containers are illustrated. Bulletin SP 4520.





Fastest Saws Give Fastest Service

With these four modern MARVEL SAWS, the Hamilton Steel Co. of Cleveland is building a reputation for fast service on orders for accurately cut lengths and pieces. They use a Universal No. 8 MARVEL Metal-cutting Band Saw for the big work (up to 18" x 18"), for angle cuts (at any angle in a 180° radius), for notching, mitering and roughing to size and shape. For high speed cutting-off from bar stock up to 10" x 10", they have three No. 9A MARVEL Production Saws. These "fastest saws built" are used for cutting-off single pieces, or with their automatic bar-push-ups, for automatically reducing single or nested bars to slices (as gear blanks) or identical lengths, faster than is possible, with equal accuracy, by any other method.

With 9 distinct types of MARVEL Metal-cutting Saws; with the positively unbreakable MARVEL High-Speed-Edge Hack Saw Blades; and, with MARVEL Band Saw Blades, the MARVEL System of Metal Sawing has a better way for doing innumerable metal-cutting jobs. If you have a difficult metal sawing problem or just want a saw, MARVEL is your logical source. Write us or check with your local MARVEL Distributor.

For quick reference see our section in Sweet's File—Mechanical Industries, or write for catalog.

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MARVEL SAWS

Metal Progress; Page 1408

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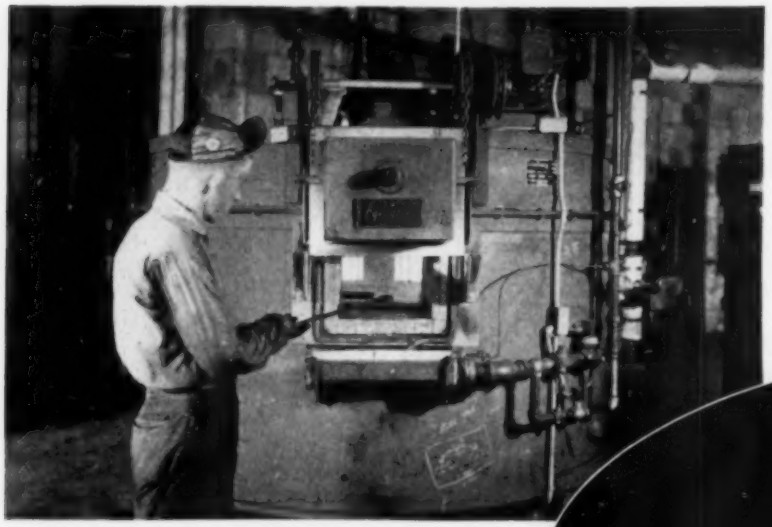

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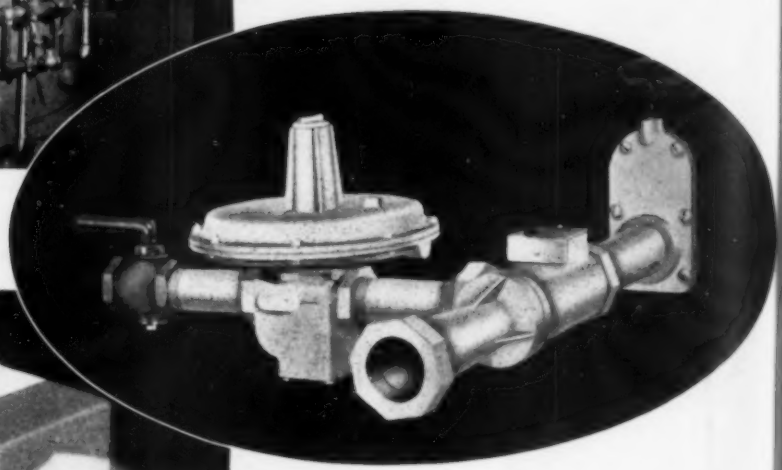
A COMPLETE LINE OF BURNERS FOR ALL INDUSTRIAL USES

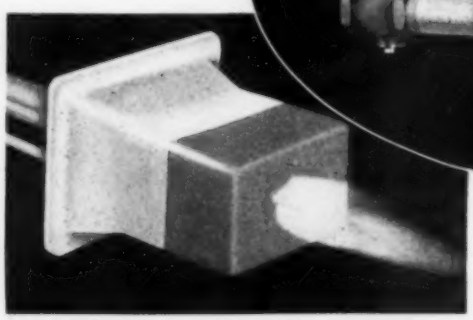
National Blast Line Burner used as curtain burner on Lindberg Hydryzing Furnace.



NATIONAL HYPERBO BURNERS

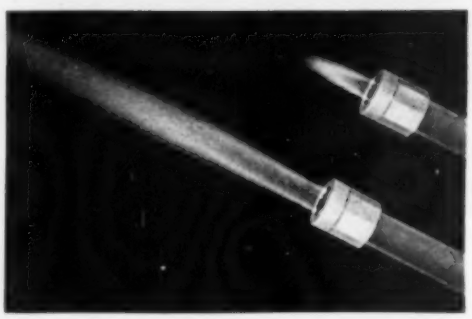
National Hyperbo Burners are sealed-in gas flame ports noted for convenience of installation, freedom from damage by reflected heat, and quiet operation. They have an exceptionally long turn-down range, ignition stability, are positively sealed against either flame leakage or air infiltration, and have a safe, integrally mounted lighting burner.

The Hyperbo Burner holds a blast flame without blow-off or smothering, with mixture pressures from 0.25" WC to 25" WC.



NATIONAL TORCH TIPS

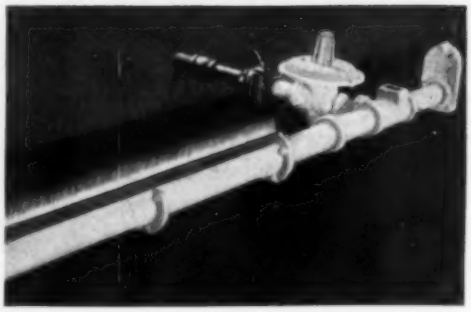
For open fired ports or tuyeres using high or low pressure gas, National Torch Tips offer a distinct advance in practical design. Numerous small orifices assure a more uniform distribution of the piloting fringe gas and hence a more stable ignition of the main jet. Nickel cast iron construction with heavy undiminished section back of the burner face provides a metallic path for the dissipation of reflected heat. Destruction of the burner face by excessive temperatures is thus prevented.



NATIONAL BLAST LINE BURNERS

When lighted or piloted at any one point, the flame travels instantly to every inch of the burner assembly. Postitive, safe ignition is thus assured in oven enclosures where parts of the burner may be inaccessible for lighting. These burners operate equally well on all types of gases.

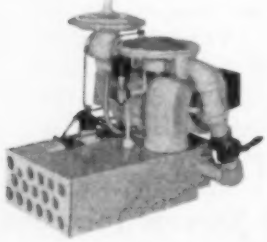
These units are showing remarkable results as furnace door curtain burners. They are also finding wide usage for flame annealing of localized areas, tempering drill shanks, heating angles, rods and tubes for bending, and relieving welding stresses.



NATIONAL PROPORTIONAL MIXERS

National Proportional Mixers employ air from a low pressure fan or blower—no compressed air needed. They thus achieve *at low cost* the recognized advantages of supplying combustion air under positive pressure. These mixers utilize the entrainment principle of a venturi to provide automatic, precise, *single valve* control of gas-air mixture ratios—eliminating the errors in judgment always possible where control of the gas and air valves is manual.

They permit an exceptionally wide range of burner turn-down—as much as 7 to 1—while maintaining CO_2 in the products of combustion within narrow limits. Only a single valve need be operated for control of both air and gas, and this can be operated either automatically or manually.



LO-BLAST POWER GAS BURNER

For firing boilers and furnaces. Introduces air under pressure into the gas stream, assuring completeness of combustion not possible with natural draft. Capacities to 5,000,000 BTU.

For complete engineering data, send for the National Manual.

NATIONAL

INDUSTRIAL GAS BURNERS

division of Mid-Continent Metal Products Co.

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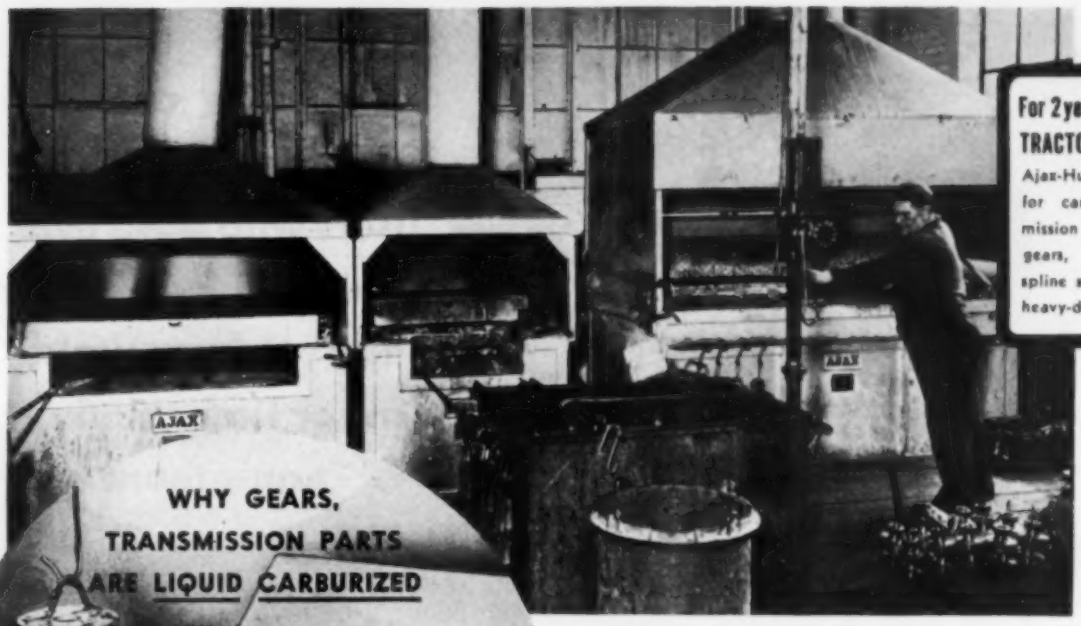

For 2 years CLEVELAND TRACTOR CO. has used Ajax-Hultgren furnaces for carburizing transmission and differential gears, stem pinions, spline shafts, and other heavy-duty tractor parts.

CLEVELAND TRACTOR CO.

REDUCED SCRAP BELOW 1/10 OF 1%

...Savings due to lowered distortion alone paid for furnaces.

Says W. A. SILLIMAN, *Chief Metallurgist*

Here are the observations of W. A. Silliman*

"Changeover from gas to salt baths has solved our major problem of distortion. It has cut rejects from 10% to zero, and on high speed parts from 50% to 1/10th of 1%. Reduction in scrap has paid for the furnaces.

"Where it was necessary to plug-quench gears in order to maintain size, it is now possible to run all of these gears by direct quench from the bath.

"The floor space now used is 1/4th that required by former methods, and the cycle has been cut from 8-hr. to 4-hr. total time. This has provided us with greatly increased output.

"We believe this due to inherent advantages of the method, the uniformity made possible by the internal heating and circulatory effect of the closely-spaced Ajax-Hultgren electrodes, as well as a more uniform quench than was possible by previous methods."

These observations were made during a recent 11-month period, during which 339,229 lb. of parts were carburized.

*From a paper "Liquid Carburizing of Transmission Gears," available on request. Write for this and Catalog 107-B.

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THE **AJAX** HULTGREN **ELECTRIC SALT BATH FURNACE**

Associate Companies: Ajax Metal Co. • Ajax Electric Furnace Corp. • Ajax Engineering Corp. • Ajax Electrothermic Corp.

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Photograph by courtesy of Matson Navigation Company

AD 10

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Holcroft HAS PIONEERED IN FURNACE ENGINEERING

Modern Holcroft gas-fired radiant tube furnace for malleable annealing of small parts in farm implement plant.

BACK in the days of the old two-horse-powered binder, when "farmer" and "laborer" were well nigh synonymous, Holcroft developed such heat treat furnace innovations as alloy conveyors for continuous-type furnaces and the removable electric heating unit. In suceeding years, Holcroft has pioneered many other improvements in furnace design—improvements which have helped lower the cost and increase the durability of today's labor-saving farm equipment and other essential metal products.

Every Holcroft furnace is individually engineered by an organization of specialists who have been a step ahead in furnace design for nearly 30 years. That's one reason you can be confident that, whatever your requirements in production heat treating, Holcroft furnaces *designed for the job* will give you the quality and volume of production desired, with the utmost economy obtainable under your own particular conditions.

Before you invest in furnace equipment for production work of any type, we invite you to take advantage of the specialized knowledge of our executives and engineers.

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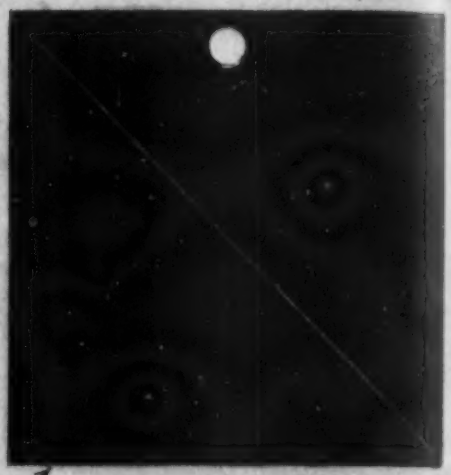
Paint Finishes Endure on Properly Cleaned and Conditioned Surfaces

The superior performance of a good paint system on a surface *properly* cleaned and conditioned with 210 B DEOXIDINE.

Even a good paint fails prematurely on a poorly prepared surface as illustrated by the Alkali cleaned panel.



CLEANED with ALKALI

CLEANED and CONDITIONED with 210 B DEOXIDINE

Identical Salt Spray Exposure

CLEAN AND CONDITION SHEET METAL with 210 B DEOXIDINE

THE 210 B DEOXIDINE process is the simplest and most advanced procedure in metal preparation for paint. A minimum of low-cost operating equipment is required therefore, less than the usual amount of operating space is needed. The fewer necessary operations cut the production costs. Time and labor are saved and better results obtained.

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210 B DEOXIDINE is ideal for completely mechanized spray process in power spray washers constructed of mild steel. A three stage washer is usually sufficient, but four stages are preferable if drawing compounds are present.

A NATURAL FOR THE SMALL PRODUCTION PLANT

210 B DEOXIDINE does not require expensive stainless steel equipment. Three stage washers which have previously been used for alkali cleaning can be used. The simplicity of controls of 210 B Deoxidine bath and process lead to uniformly good results.

210 B DEOXIDINE is but one of several war-proved Deoxidines — each created to meet differing conditions. ACP Technicians will gladly advise with you and suggest the particular ACP products and processes which will efficiently meet your cleaning and conditioning problems. Write to Dept. L-12.

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Immediate shipment from seven conveniently located stocks.

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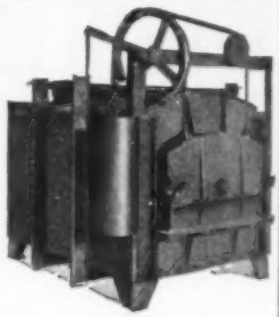
HEAT TREATING FURNACES



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Overfired and bottom vented with vent passages under tile floor. Uniform temperature and high efficiency. First grade fire brick or insulating refractory brick lining. Furnaces are manually or automatically controlled.

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Write for Bulletin M-550

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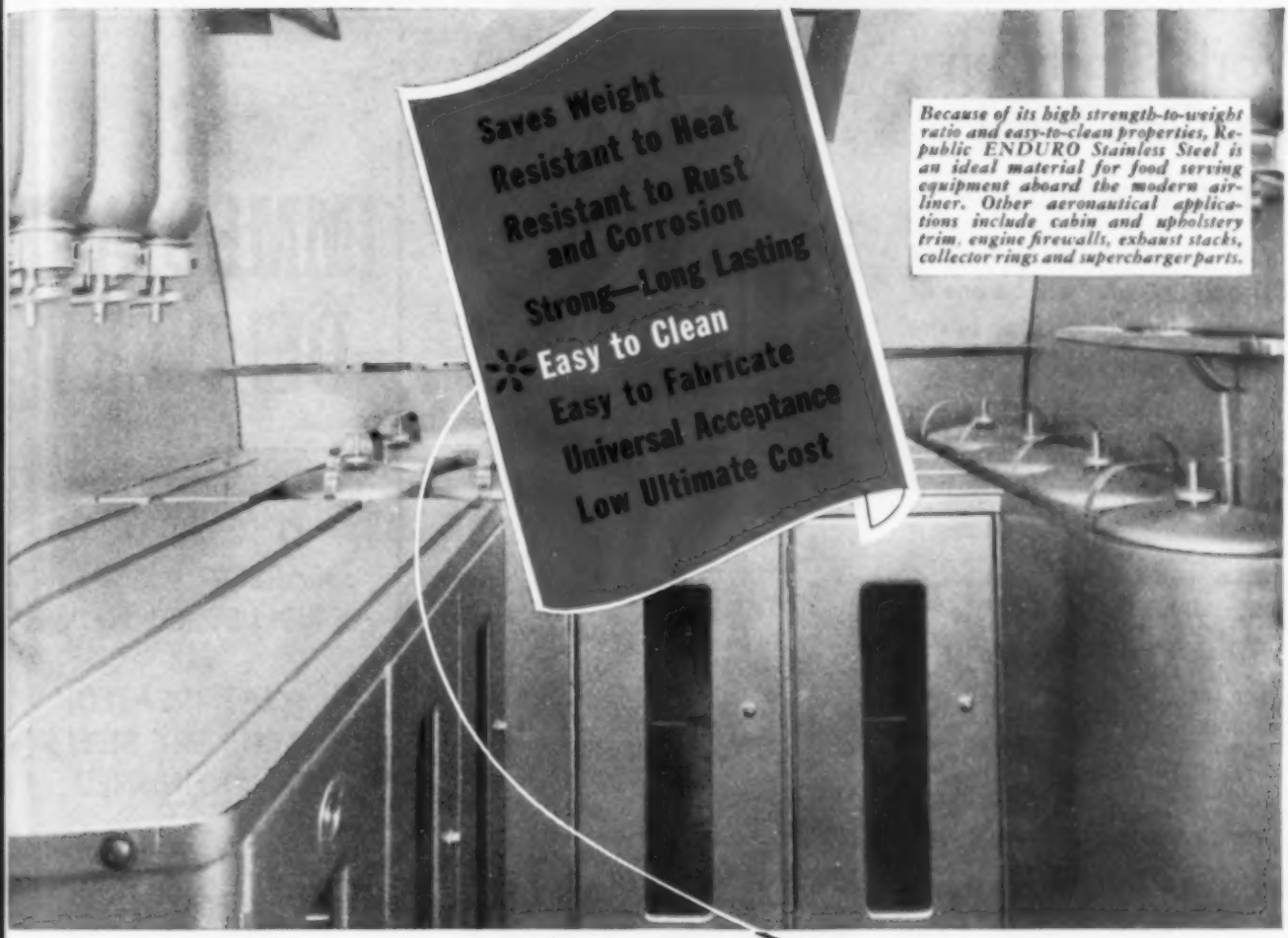

Because of its high strength-to-weight ratio and easy-to-clean properties, Republic ENDURO Stainless Steel is an ideal material for food serving equipment aboard the modern airliner. Other aeronautical applications include cabin and upholstery trim, engine firewalls, exhaust stacks, collector rings and supercharger parts.

Enduro Pays in many ways

Republic ENDURO Stainless Steel—the metal that's clean and as easy to keep clean as glass—is the ideal material for all types of food handling and preparation equipment aboard modern airliners.

Ordinarily, a damp cloth is all that's required to restore ENDURO's sparkling, sanitary appearance in a hurry. For sticky or greasy substances, warm soapy water does a thorough cleaning job with a minimum of time and effort. And no matter how many times it is cleaned, ENDURO retains its lustrous surface—because it is solid stainless steel all the way through.

For further information about these and other money-saving reasons for using Republic ENDURO Stainless Steel, write *today* to:

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Work Starts on Brazilian Steel Plant Foundry

Dual purpose facility to cost $1,850,000 and will be one of most unusual foundries in the Western Hemisphere

CONSTRUCTION of a foundry—one of the most unusual in the Western Hemisphere—for the large Brazilian National Steel project at Volta Redonda, Brazil, has been started.

The foundry, according to Roy I. Jones, head of the Industrial Engineering Division of Giffels & Vallet Inc., L. Rossetti, associated engineers and architects, Detroit, who designed the complete foundry project, will produce ingot molds and stools, iron grain and chilled rolls, steel rolls, miscellaneous iron, steel and nonferrous castings. The foundry which will cost approximately $1,850,000 will pioneer in many ways the reduction of hand labor and the improving of working conditions in the Brazilian foundry industry.

The foundry is a dual purpose facility. Half of the space is devoted to highly mechanized production systems for the regular supply of ingot molds and stools. The remaining half of the foundry is primarily for production of castings to keep the mill equipment in constant operation, and has facilities and equipment capable of producing any casting in the entire steel mill.

The foundry is designed so that ingot molds may be poured with hot blast furnace metal direct from the open-hearth mixers. Its equipment includes a cupola, air furnace, electric furnace, monophase furnace, nonferrous metal furnace, annealing furnaces, pit type ingot mold ovens, a completely mechanized sand conditioning and distribution system, casting and cleaning equipment, roll turning lathes, and ingot mold milling equipment.

The jobbing nature of this foundry's operations requires that it be, in addition to an ingot mold foundry, a steel foundry one week, an iron foundry the next, and perhaps a roll foundry the following week. This gave rise to the requirement that, in addition to the charging of the cupola, the arc furnace and air furnace would need to be charged at various times both with cold charges and with hot charges for duplexing.

The foundry has been designed for ready expansion to provide an additional 150 per cent capacity. Construction of the foundry is expected to be completed in about nine months, about the time when the main portion of the steel mill will be completed.

Reprinted from STEEL Magazine

R-S

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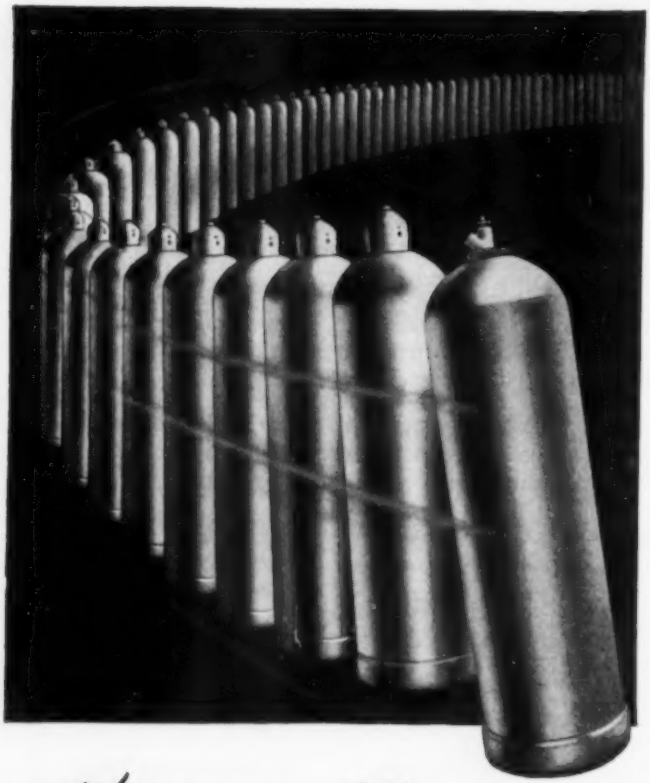

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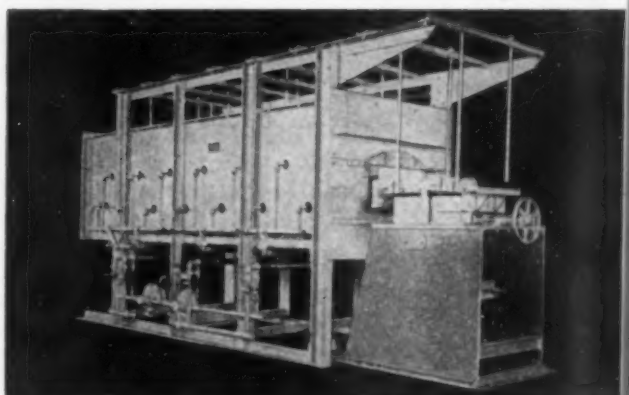

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VERSATILE. Adaptable to a countless variety of work from needles to large forgings. These furnaces may be used for hardening, annealing, normalizing, etc.

SIMPLE. Simply-designed mechanism is out of the heat while the muffle remains in the furnace at all times. Work is in constant motion and so cannot stick to the hearth.

ATMOSPHERE CONTROL. A full muffle is utilized, making it possible to maintain a definite atmosphere around the work. This widens the range of usefulness to include clean hardening, carburizing, and "NI-Carbing".

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For complete information on all types of box, tube, muffle or pit high-temperature furnaces, write for Burrell Catalog F-241.

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• REMEMBER "way back when" . . as youngsters . . we first encountered that jolly ol' fellow pictured above? For weeks his arrival was looked forward to and when, on Christmas eve or Christmas morn, he popped in with "almost" all the gifts we had hoped for—what a thrill that was. His annual visit really left us with an *IMPRESSION THAT LASTED!*

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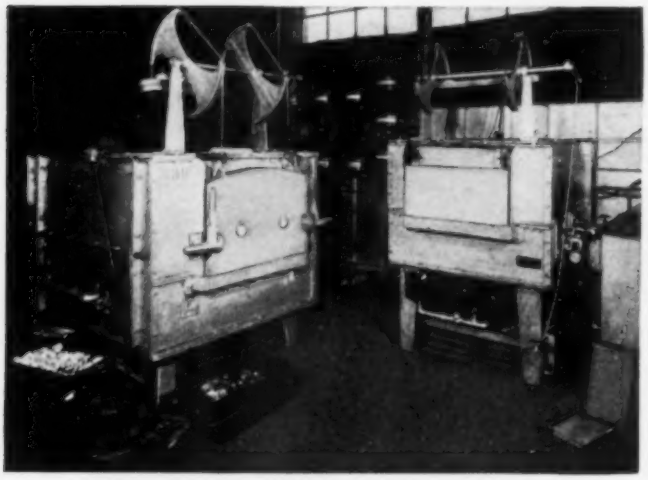


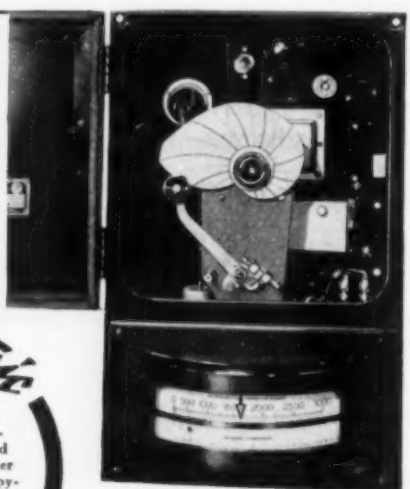
"Programs" for Heat Treating Saw Blades

Heat treatment of hack saw blades presented an interesting problem to Armstrong-Blum Company, Chicago, manufacturers of the famous "Marvel" line of metal cutting saws.

To secure the necessary hardness and toughness, as well as other metallurgical characteristics, it was necessary to follow a precise cycle of temperature control. This was achieved by the use of Wheelco "Electronic Control Principle" Program Controllers on the furnaces, with Wheelco indicating pyrometers for signalling.

These Wheelco Universal Type CHRONOTROLS regulate temperature automatically, by means of a synchronous motor driven disc that is contoured to suit the control cycle desired. The disc moves an arm that is mechanically coupled to the temperature setting lever of the Capacitrol or Potentiotrol section of the controller. This Wheelco control setup was chosen by Armstrong-Blum to secure highest available precision, reliability, and simplicity.

Illustration at the top shows the Wheelco control panel and two Barkling furnaces. At the right is a Wheelco Chronotrol, with door open to show a typical contoured disc.



Electronic Controls

The WHEELCO complete line includes Flameotrol combustion safeguard . . . Capacitrol pyrometer controllers . . . Indicating pyrometers . . . Proportioning controls . . . Program controls . . . and a wide range of accessories.

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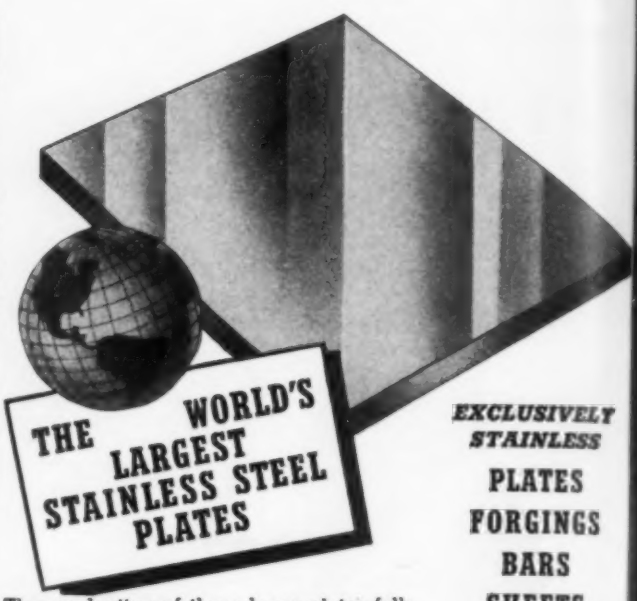
Creators of "Electronic Principle" Temperature Controls



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PLATES
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BARS
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AND
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The production of these large plates falls within the classification of routine production at G. O. Carlson, Inc. We are particularly well equipped both in engineering experience and facilities to produce almost any quantity of stainless steel in the forms listed at right. Call us for quality service on your next job.

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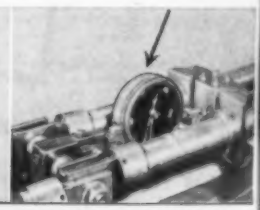
Service

For Every

LOAD OR TENSION



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Imagine a can towering 7 miles into the stratosphere, with a base broad enough to cover downtown Pittsburgh—a container of such gigantic capacity that all the water roaring over Niagara Falls in 2 years couldn't fill it.

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This large demand for Weirton tin plate, like the extensive market for Weirton's many other products, is the natural result of Weirton Steel Company's rigid control of quality in all manufacturing operations.

Weirton has the *facilities* for quality. Its management, with constant emphasis on advanced steel making practice, has been an international factor in progressive industrial thinking. And, its completely integrated steel mill is an outstanding example of what modern equipment can mean in maintaining strict product standards.

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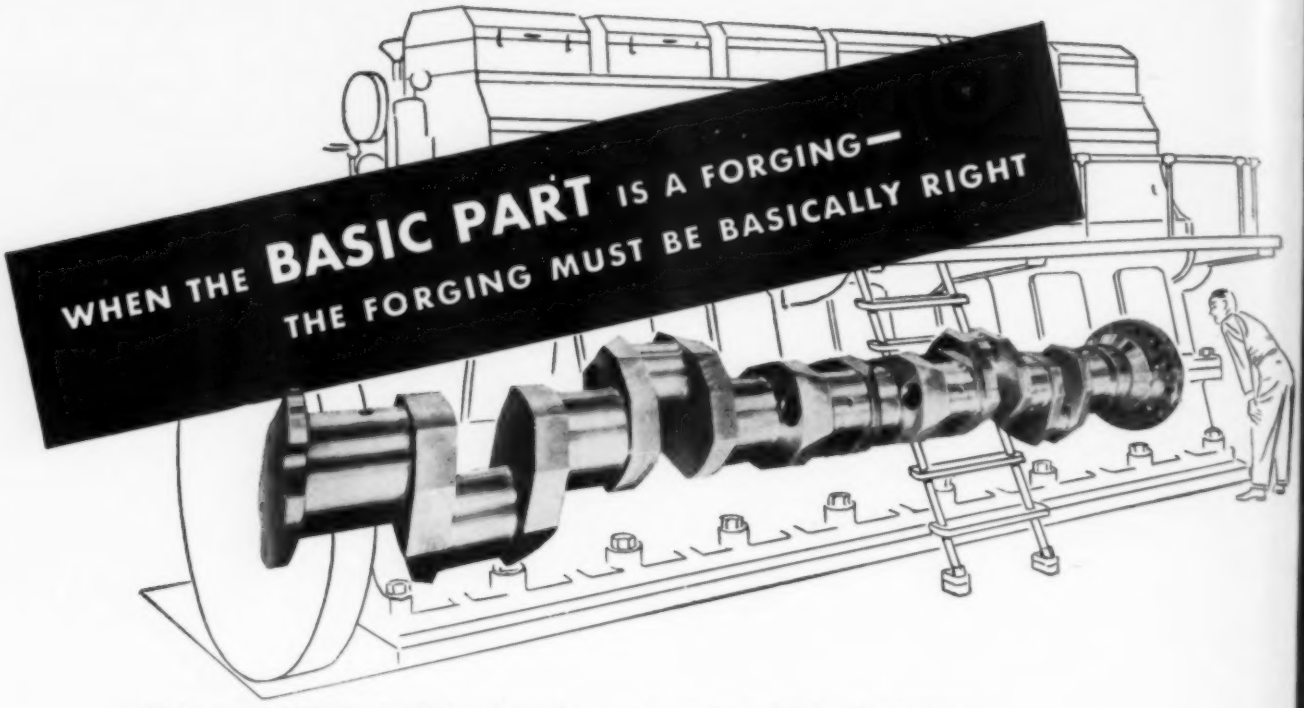

The crankshaft of a Diesel engine—the rotor shaft of a steam turbine—the spindle of a machine tool are typical of the "basic" functions forgings must perform in making engines, power plants and machinery live up to "their good name" in actual service.

When you buy such a forging, you want faithful adherence to specifications but you also want something more. You want an inherent quality that spells longevity and freedom from trouble. To possess these qualities a forging must be born of clean steel and handled with constant skill through all the critical stages of forging, heat treating and precision machining.

It takes equipment, experience and men who really have the "know how" to produce that kind of forging—and that is the only kind of forging worth while buying, if your reputation hinges on how that forging performs. Let National Forge tell you about it now, for National Forge can serve you now.

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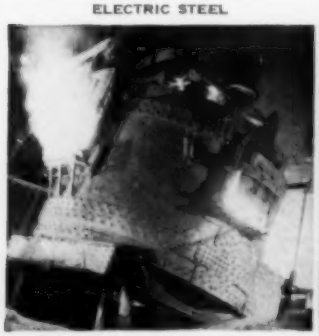
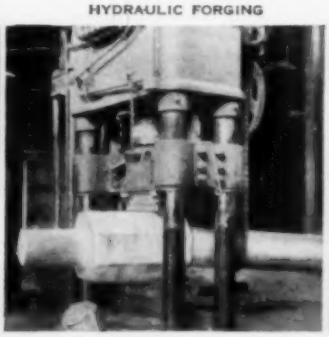


HYDRAULIC FORGING



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Tool Steels

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SEE OUR DISPLAY—BOOTH A-401—NATIONAL METAL CONGRESS
Cleveland, February 4-8, 1946

Vanadium-Alloys

STEEL COMPANY

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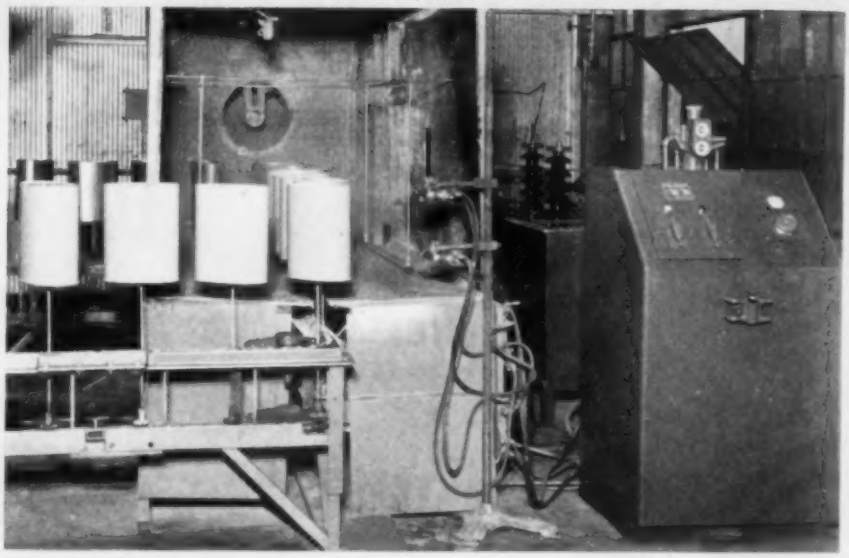
WITH 1/3 THE MANPOWER
WITH LESS THAN 1/2 THE PAINT

TWENTY **wastebaskets a minute** ***(with no skilled operator!)*** **are painted in this Midwestern factory, where** ***two skilled*** **painters previously finished only** ***seven*** **baskets a minute.**

With Ransburg equipment, two unskilled employes (to load and unload the conveyor) now do the work of ***six skilled sprayers and six loaders!***



REVOLUTIONARY and *exclusive,* Ransburg equipment introduces paint, at low velocity, into an electrostatic field established between charged electrodes and the grounded article to be painted. Paint particles are charged by the electrodes, and thus are drawn to the article's *entire* surface—evenly, and with negligible waste!

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With Ransburg processes, payrolls go *down* . . . quality of workmanship goes *up* . . . *paint consumption drops 50%* . . . whether your conveyor is monorail, overhead, spindle or belt-type.

Consuming less power than a 1,000-watt lamp, Ransburg equipment is *adaptable to all spray guns and atomizable finishing materials* (lacquer, enamel, oil, wax and water-suspensions). Smaller overspray means far less booth-cleaning.

Ransburg equipment requires less ventilation and maintenance . . . and is capable of any production speed desired.

Write for the illustrated Ransburg folder. A statement of your conveyor-painting requirements will place our engineers at your service.

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Electrostatic
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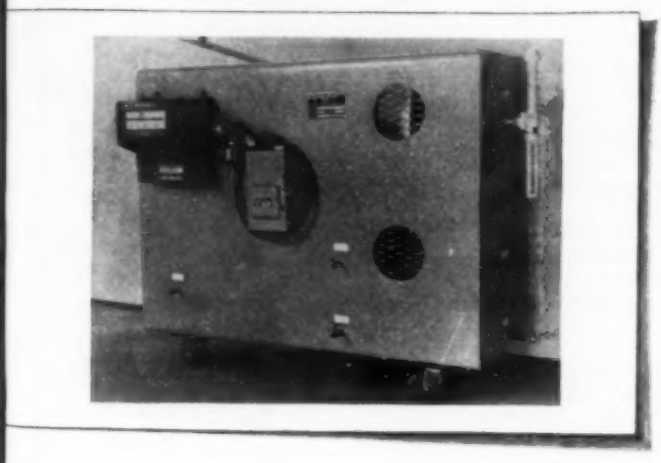
The **UNIVERSAL GAS ATMOSPHERE GENERATOR** satisfies a long felt want in most manufacturing plants and research laboratories. The generator is universal in that it can be used as an **EXOTHERMIC GAS GENERATOR, ENDOTHERMIC GAS CRACKER** or as an **AMMONIA DISSOCIATOR.** The one unit is complete with gas mixing machine, catalyst furnace, retort, gas cooling condenser, control valves, automatic temperature control, flow scope, pressure gauges and pressure regulator. It is shipped set up ready for operation.

OUTPUT CAPACITY of all units is instantly variable, the laboratory unit output is 10 to 50 c.f.h., the #100 unit variable from 50 to 100 c.f.h. and the #250 unit variable from 150 to 250 c.f.h. Single reaction generators are made in sizes up to 2000 c.f.h.

POWER REQUIREMENTS for the laboratory generator is 1500 watts, for the #100, 4 KW and for the #250, 7 KW. A minimum supply of water is used for cooling purposes since finned tube heat exchangers are used. **FLOOR SPACE** requirements are 8, 12 and 14 square feet respectively.



ENDOTHERMIC REACTION —

18% CO, 34% H_2, 46% N_2, 1% CO_2 (Lean Ratio) 70°F. Dew Point

19% CO, 40% H_2, 40% N_2, 0% CO_2 (Rich Ratio) —15°F. Dew Point

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0.5% CO, 0.5% H_2, 89% N_2, 10% CO_2 (Lean Ratio) 70°F. Dew Point

10% CO, 15% H_2, 70% N_2, 4% CO_2 (Rich Ratio) 70°F. Dew Point

AMMONIA DISSOCIATION —

75% H_2, 25% N_2 (Residual Ammonia .05%) —50°F. Dew Point

The chief features which make it desirable are:

COMPACT, All necessary parts enclosed or mounted.

MOBILE, Casing mounted on silent casters.

UNIVERSAL, Three units condensed in one.

SERVICES, Electric, gas and water by flexible connections.

HEAT-POWER EQUIPMENT

REGISTERED PROFESSIONAL ENGINEERS, CONSULTING MECHANICAL AND POWER PLANT ENGINEERS, DESIGNERS AND CONSTRUCTORS OF SPECIAL MACHINERY, CHEMICAL PROCESSING AND DRYING EQUIPMENT, INDUSTRIAL FURNACE AND OVEN INSTALLATIONS, HYDROGEN AND INERT GAS GENERATING AND PURIFYING EQUIPMENT.

Inventory time or any time . . . MILNE

KOLORKOTE

saves you Time, Waste, Trouble

MILNE TOOL STEELS are identified by overall coatings of various lacquer colors sprayed the entire length of the bars. This method, developed by Milne, corrects the obvious disadvantages of the common practice of marking the bar ends.

KOLORKOTE offers these advantages to any manufacturer who keeps a stock of tool steel on hand:

1. **The grade can be readily identified, no matter how much has been cut from the bar, because the entire surface is completely coated with color.**
2. **Short ends of one grade of steel will not be misplaced with other grades. But if space is limited, they can be racked together without losing their identity.**
3. **Bar pieces retain their distinguishing colors in the machine shop, preventing errors.**
4. **Furnacemen know what grade they are working, and properly heat treat it, preventing spoilage.**
5. **Stock clerks can tell at a glance how much steel of various grades they have on hand, improving records and assuring much higher scrap values.**
6. **Wherever workmen do not understand English, brand names and labels mean little, but COLOR IS UNIVERSAL.**

KOLORKOTE adds a plus to the proved advantages of Milne Tool Steels for every metal cutting and forming need. **KOLORKOTE** wall chart, with exact colors, and heat treating information, free on request, from the Milne office near you.

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Get it
Faster-from Stock-
from MILNE
5
convenient warehouses

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TOOL STEELS
High Speed,
Alloy, and Carbon

HOLLOW, SOLID,
AND AUGER
DRILL STEELS
for all mining
and excavation work

BYERS GENUINE WROUGHT IRON BARS
To A.S.T.M. Specification A-189
To A.A.R. Specification M-302
To U. S. Navy
Specification 46-1-7C of May 1, 1944

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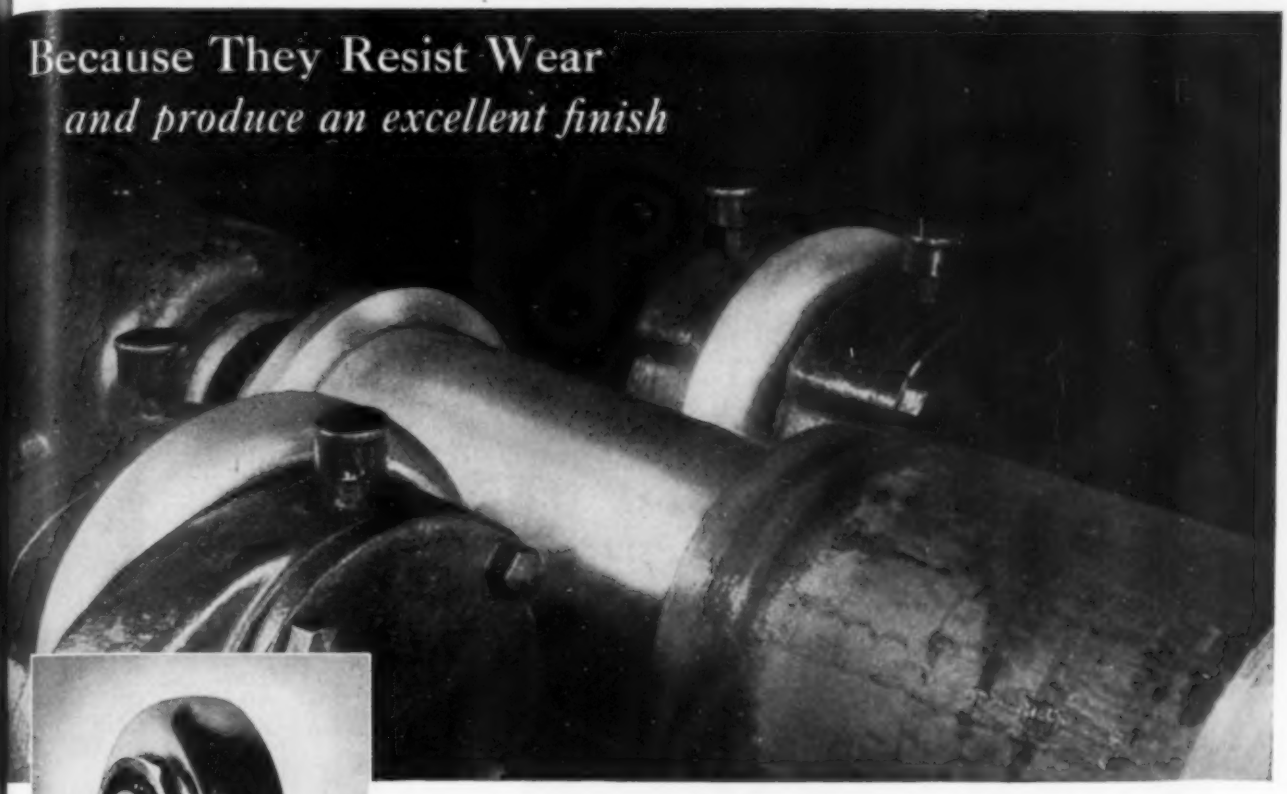
GRAPHITIC STEELS
Machine Faster
Wear Longer

STRESSPROOF
T.M. Reg. U.S. Pat. Off.
STEEL
COLD DRAWN — FURNACE TREATED
"More than just strain-relieved."
"HIGHER IN-THE-BAR PHYSICALS"

NITRALLOY TYPE G 135 MODIFIED (AIRCRAFT) TO AMS 6470-A

also carried in Warehouse Stock

Because They Resist Wear
and produce an excellent finish



HAYNES STELLITE Burnishing Rollers are widely used in railroad shops

More than 100,000 car axles have been burnished in one railroad shop with one set of HAYNES STELLITE burnishing rollers. In eight years of hard service these rollers of cobalt-base alloy have required no repair or maintenance, except lubrication.

HAYNES STELLITE rollers not only resist wear, but also retain their high polish, and burnish to a high degree of smoothness. And because they are essentially non-magnetic, they are unlikely to pick up steel particles that will mar the work.

HAYNES STELLITE alloys are used in many tough industrial jobs where hard, abrasion- and corrosion-resistant metals are needed. Our engineers will be glad to help you use them. For further information, write for the booklet, "Products of Haynes Stellite Company."

BUY AND HOLD UNITED STATES VICTORY BONDS AND STAMPS

In HAYNES STELLITE Alloys you can get these advantages:

1. Resistance to wear and abrasion.
2. Hardness even at red heat.
3. Good mechanical properties at high temperatures over long periods of time.
4. Resistance to atmospheric corrosion and corrosive chemicals.
5. Low co-efficient of friction.
6. Practically non-magnetic.
7. Available in the form of castings, small sheets, and welding rod.

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Unit of Union Carbide and Carbon Corporation

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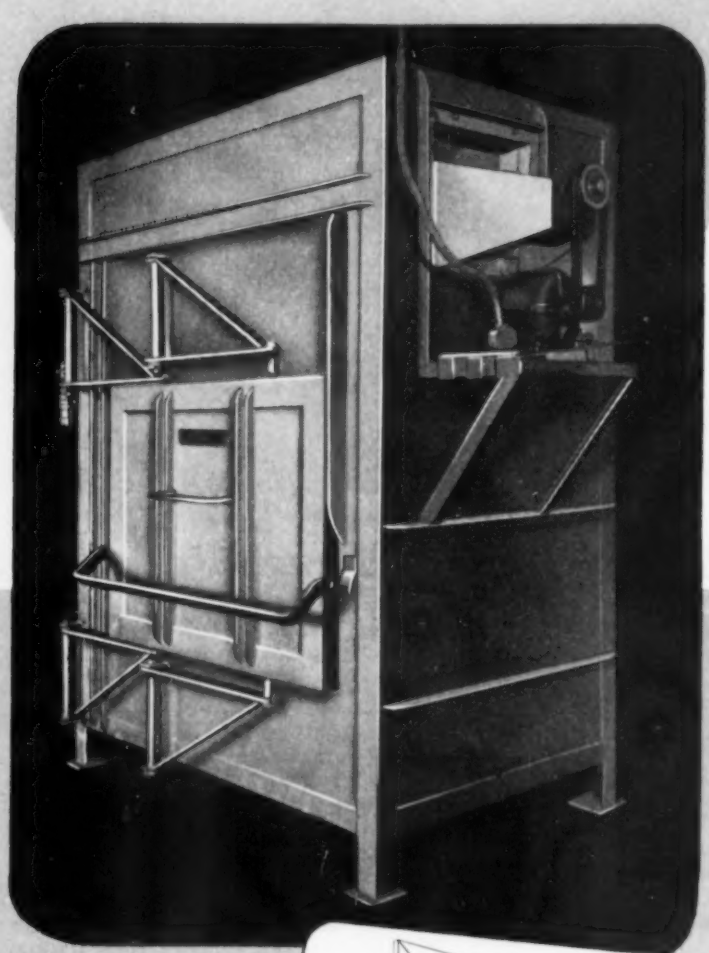
LANSING RECIRCULATING DRAW FURNACE

Gas fired, is built for specialized work on tools and loads where shapes and quantities are contantly changing. Recirculating fan, auxiliary fan and shaft assembly is easily removable in one unit by removing six cap screws—a LANSING feature.



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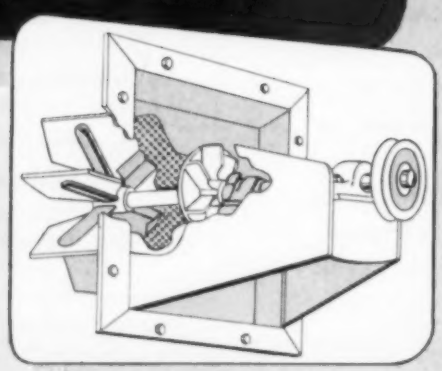
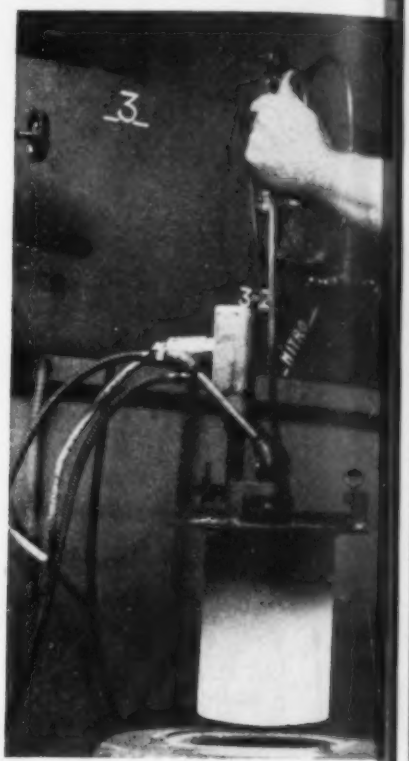


Integral Assembly of Recirculating unit, quickly and easily removable by removing six cap screws.

LANSING ENGINEERING CO. 934-36 Clark Street LANSING 6 MICH.

"LAB-TYP"



CONTROLLED ATMOSPHERES

In Your Laboratory

"LAB-TYP" HEAT TREATING ATMOSPHERE FURNACES fill the need for standard laboratory equipment for appraising the effects of various atmospheres on metals at elevated temperatures—**for small quantity work.**

RETORT

Gas tight retort measures 4½" inside diameter with working space 6" deep. Retort atmosphere is entirely separated from furnace chamber. Temperatures inside retort are obtainable up to 1825° F.

FURNACE

Furnace unit is complete with built-in transformer, relay, and thermocouple. Can be supplied with either manual or automatic control. Can also be used as pot furnace for salt or lead bath tempering and annealing.

Ask for Bulletin LT-45

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BECAUSE Norton Boron Carbide is the hardest material commercially produced, NORBIDE* products have become pacemakers in the metal industries. NORBIDE plug gages have lasted more than a year and a half on jobs where steel gages wore out in four hours. This same exceptional wear-resistance has enabled NORBIDE blast nozzles, extrusion dies, thread guides, etc., to outlast conventional materials a thousand times and more. NORBIDE abrasive successfully replaces diamond powder in many lapping operations. NORBIDE metallurgical compound is an economical source of boron for introduction into steel melts.

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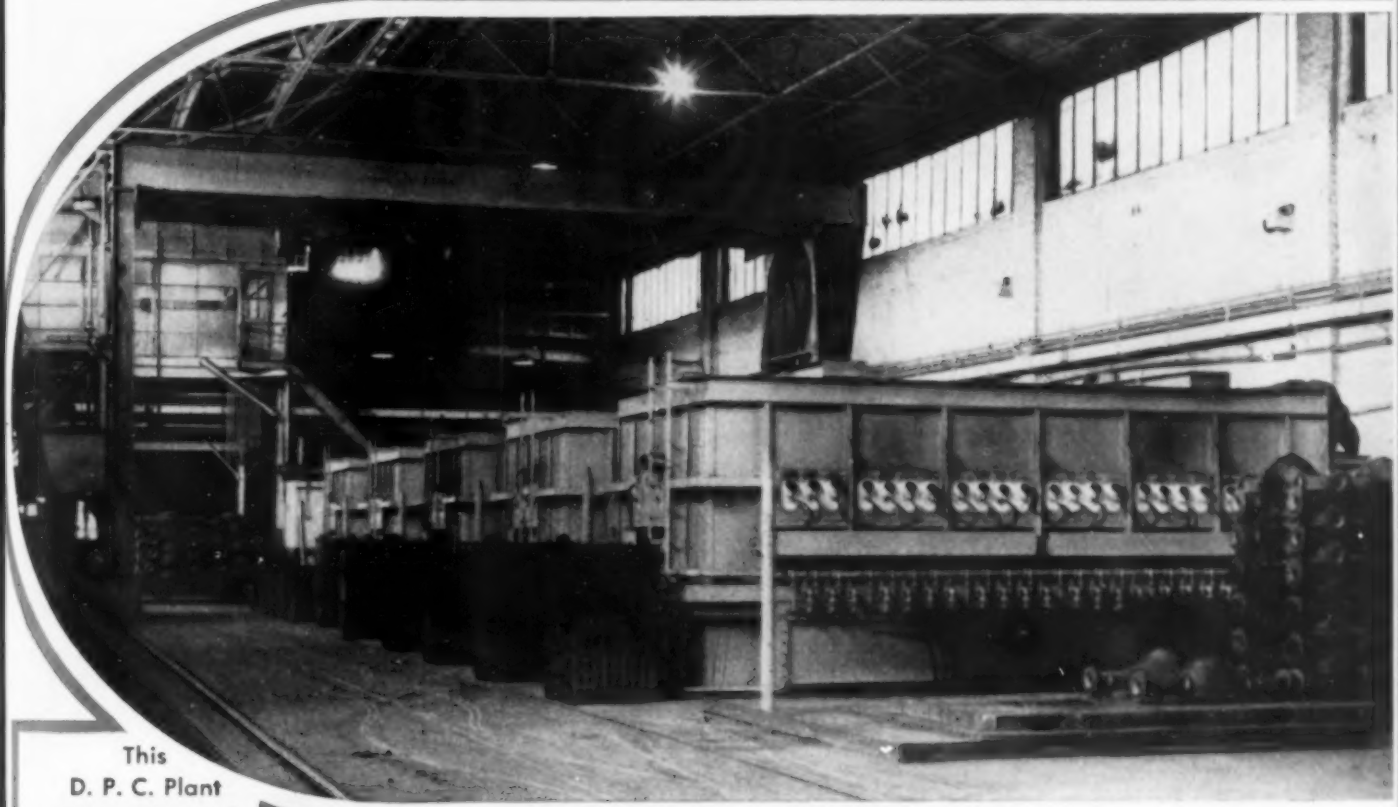
This WILSON Installation OF 5

RADIANT TUBE BELL TYPE *Furnaces*

has now served the ALBION MALLEABLE IRON Company of Albion, Michigan . . . . . FOR OVER A YEAR



This D. P. C. Plant was engineered by HOPKINS & KENDALL Alliance, Ohio

This installation called for special methods for lifting these 25-TON PORTABLE FURNACES. Note the special type gantry crane developed for existing light building. Note special alloy crates for medium and small castings.

THE economies, self-generated atmosphere, and overall cleanliness of this annealing method for malleableizing iron castings are available for all plants in the industry. Send for the Wilson Engineer to assist you in applying this equipment to your own plant conditions.

The Wilson Annealing Unit is covered by Patents Nos. 1,952,402, 2,068,477, 2,078,356, 2,081,612, 2,089,843, and other patents pending.

Lee Wilson ENGINEERING Co., Inc.

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Telephone ACademy 4670

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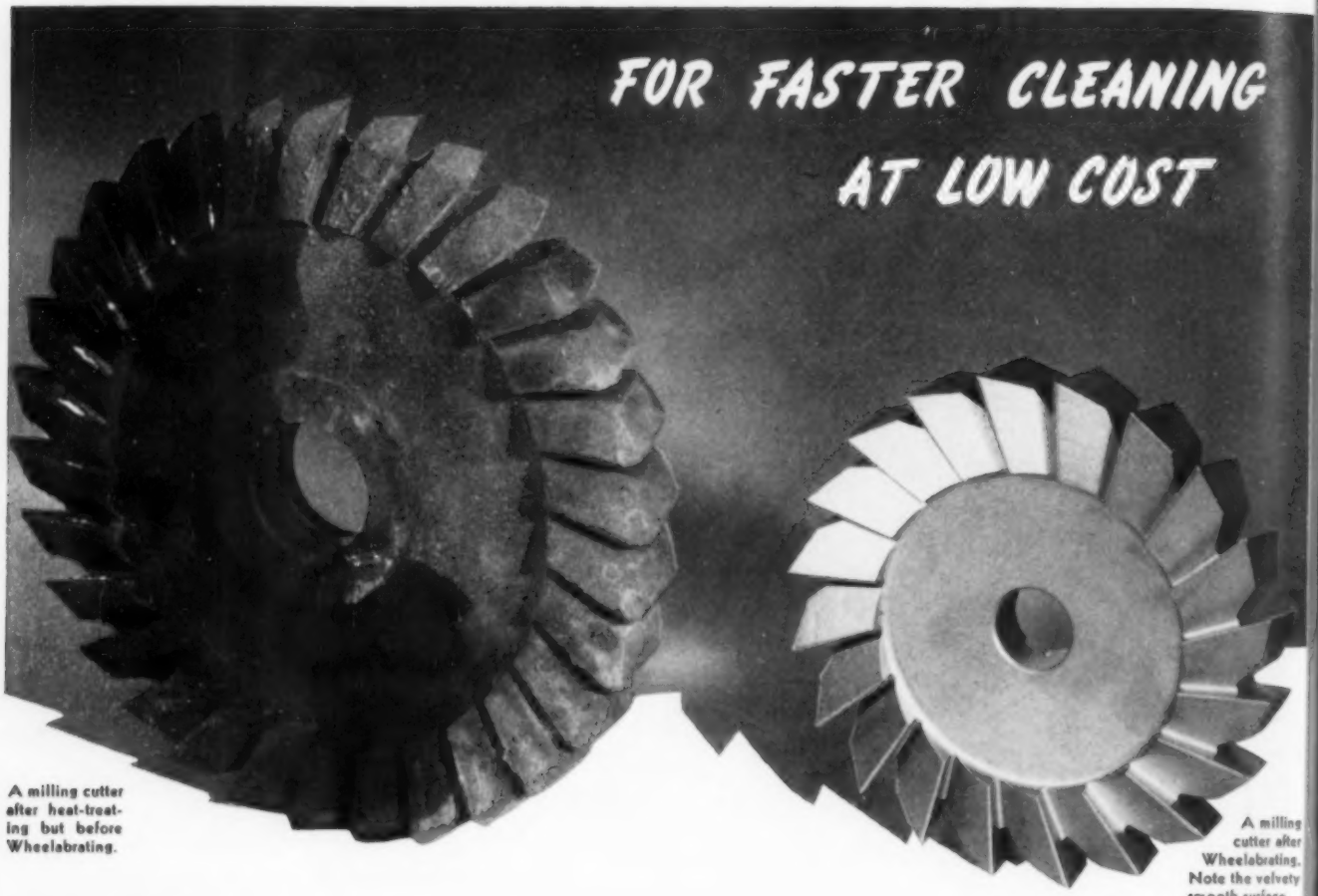
INDUSTRIAL FURNACES * RADIANT TUBE HEATING * HEAT TREATING PROCESSES



A milling cutter after heat-treating but before Wheelabrating.

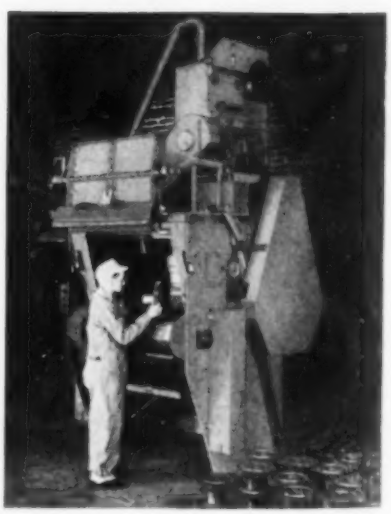
A milling cutter after Wheelabrating. Note the velvety smooth surface.

Wheelabrate HEAT-TREATED PARTS

The Perfection Tool and Metal Heat-treating Company of Chicago, using three airless Wheelabrator Tumblasts, reports that these machines speedily and efficiently remove scale deposited on tools and parts, both after heat-treating, and in preparation for it. They have found that Wheelabrating produces a velvety appearance that eliminates a great deal of expensive grinding.

The Wheelabrator Tumblast cleans batches of parts quickly, using minimum power and without damaging pieces of thin section. It employs the exclusive American endless apron conveyor principle of tumbling which provides *complete* exposure of all work to the action of the blast stream. Unloading is accomplished by simply reversing the conveyor. No other tumbling method can match the effectiveness of this design.

The performance of the Wheelabrator Tumblast as a time-saver and cost-cutter has long been recognized in hundreds upon hundreds of plants. For complete information about the airless Wheelabrator method of blast cleaning write for Catalog No. 74.



Operator inspecting a Wheelabrated gear in a 27" x 36" Wheelabrator Tumblast.

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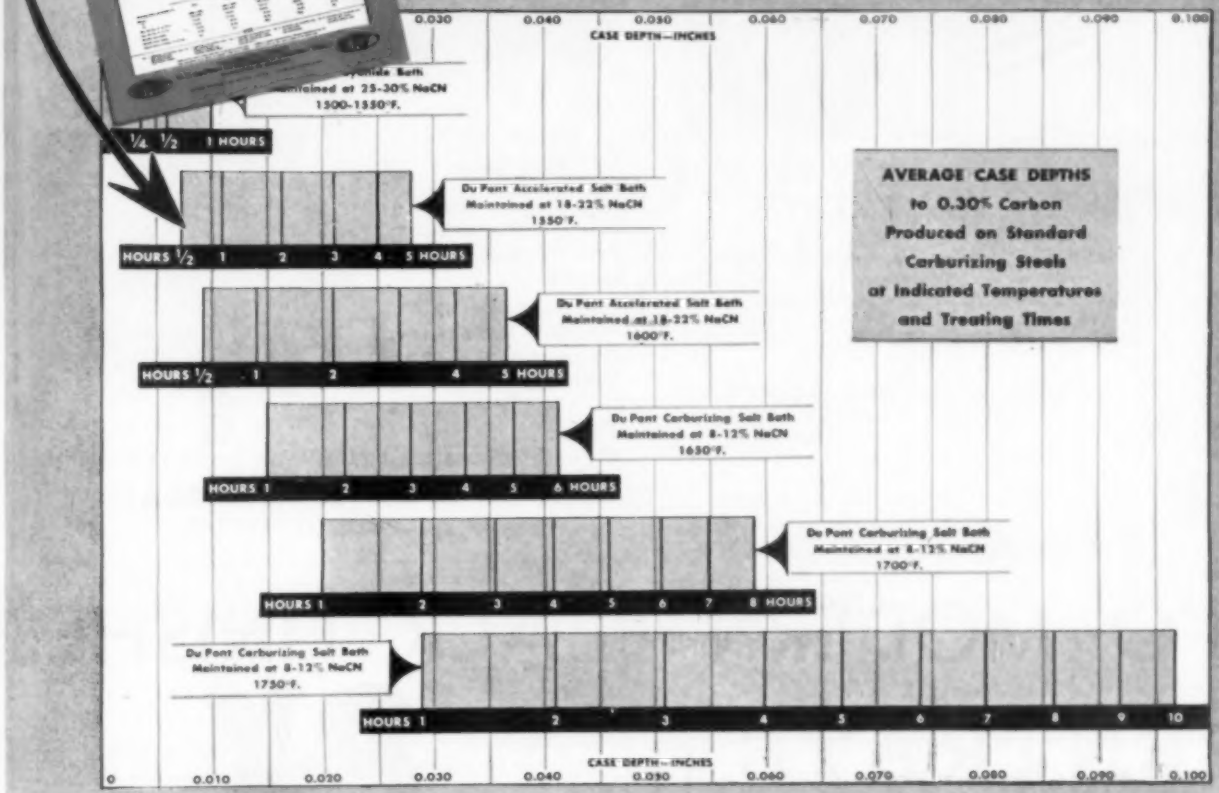
WORLD'S LARGEST BUILDERS OF AIRLESS BLAST EQUIPMENT

Get this useful heat treating guide NOW!

Du Pont's New Wall Chart will help you select the *right* case hardening compound or salt for a particular job


CASE DEPTH—INCHES
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100
¼ ½ 1 HOURS
Du Pont Accelerated Salt Bath Maintained at 18-22% NaCN 1550°F.
HOURS ½ 1 2 3 4 5 HOURS
Du Pont Accelerated Salt Bath Maintained at 18-22% NaCN 1600°F.
HOURS ½ 1 2 4 5 HOURS
Du Pont Carburizing Salt Bath Maintained at 8-12% NaCN 1650°F.
HOURS 1 2 3 4 5 6 HOURS
Du Pont Carburizing Salt Bath Maintained at 8-12% NaCN 1700°F.
HOURS 1 2 3 4 5 6 7 8 HOURS
Du Pont Carburizing Salt Bath Maintained at 8-12% NaCN 1750°F.
HOURS 1 2 3 4 5 6 7 8 9 10
AVERAGE CASE DEPTHS to 0.30% Carbon Produced on Standard Carburizing Steels at Indicated Temperatures and Treating Times
0
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
0.100

WHICH salt? Bath temperature? Treating time? Case depth? A glance at this new reference chart will give you the answers.

You can use it for a quick determination of the treating time and temperature to develop a specified case depth. Also, it will help you select the most advantageous bath to meet the treating conditions.

There is also a convenient table showing physical properties of Du Pont Heat Treating salts — a useful guide for selection and make-up of these baths.

We'll be glad to help you with specific problems. The recommendations of our metallurgists are based on many years of practical experience in steel treating.

Send for your Case Hardening Chart today! It's 20″x29″, attractively printed in 3 colors — handy to mount — easy to refer to. And it's *free!* Just clip the coupon below!

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for Steel Treating

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Please send Wall Chart for Du Pont Case Hardening Salts.

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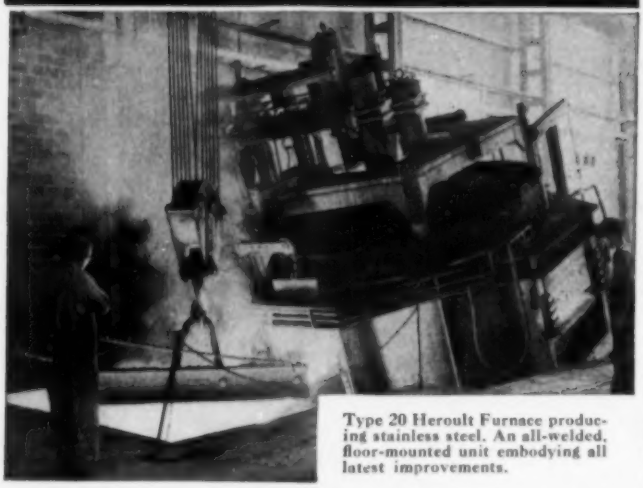
Firm_____ Title_____

Address_____

Heroult ELECTRIC FURNACES



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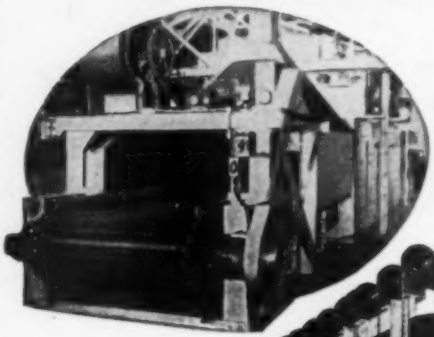
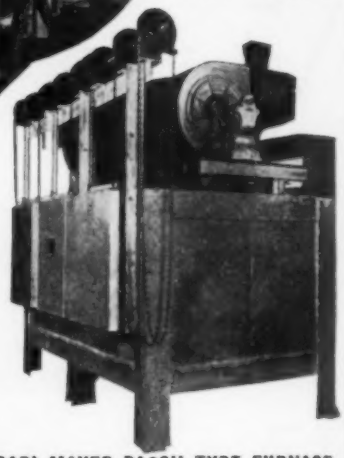


Furnaces
Continuous Type as used by Bridgeport Brass, General Motors, Timken, etc.



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Carl-Mayer Recirculating Air Heater Batch Type Furnace such as used by

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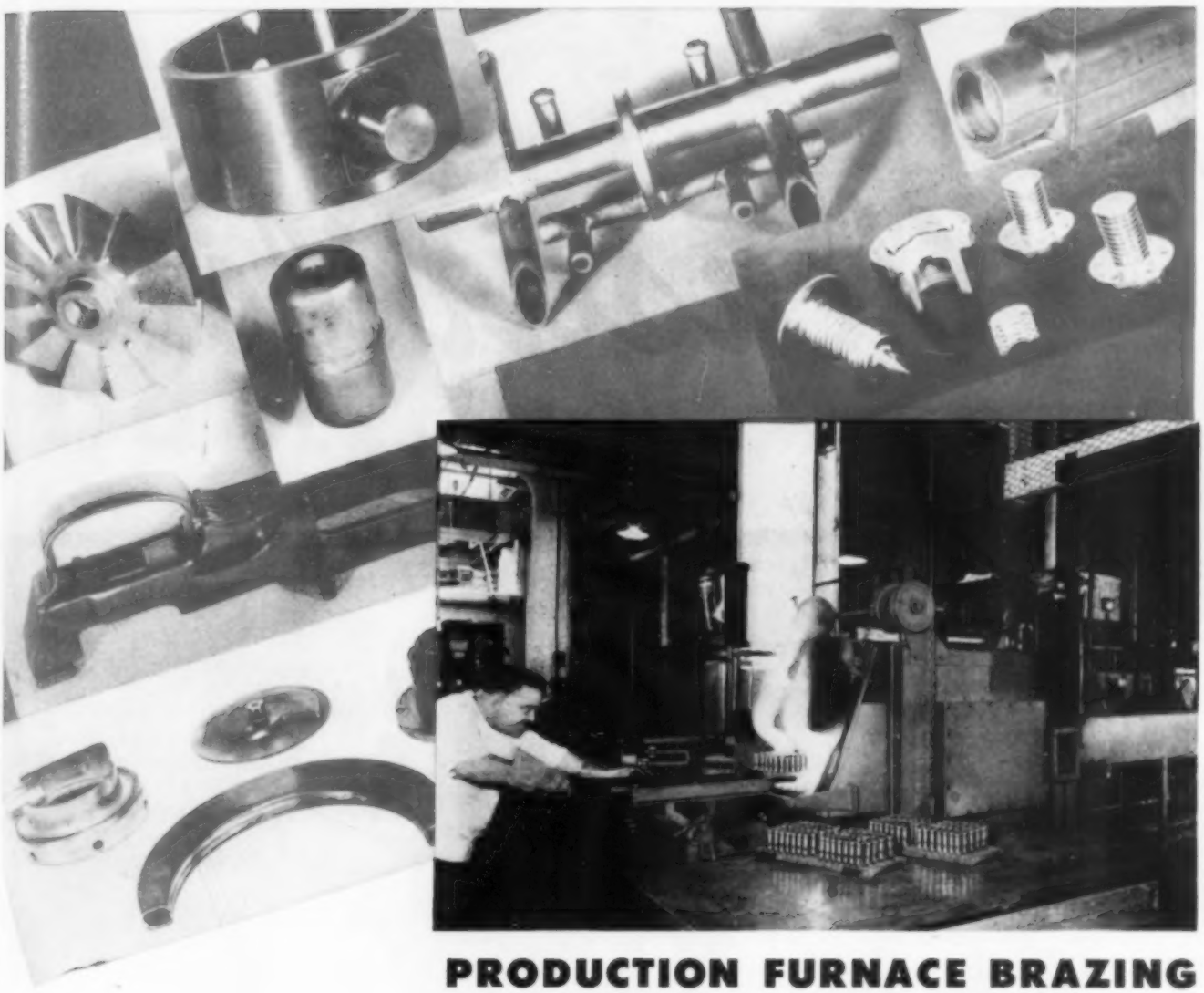

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ood Processing & Packing Plant
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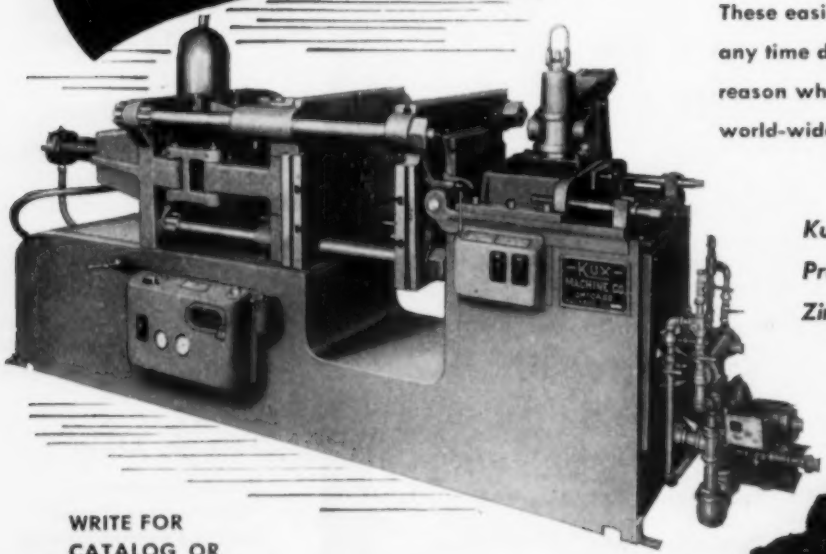

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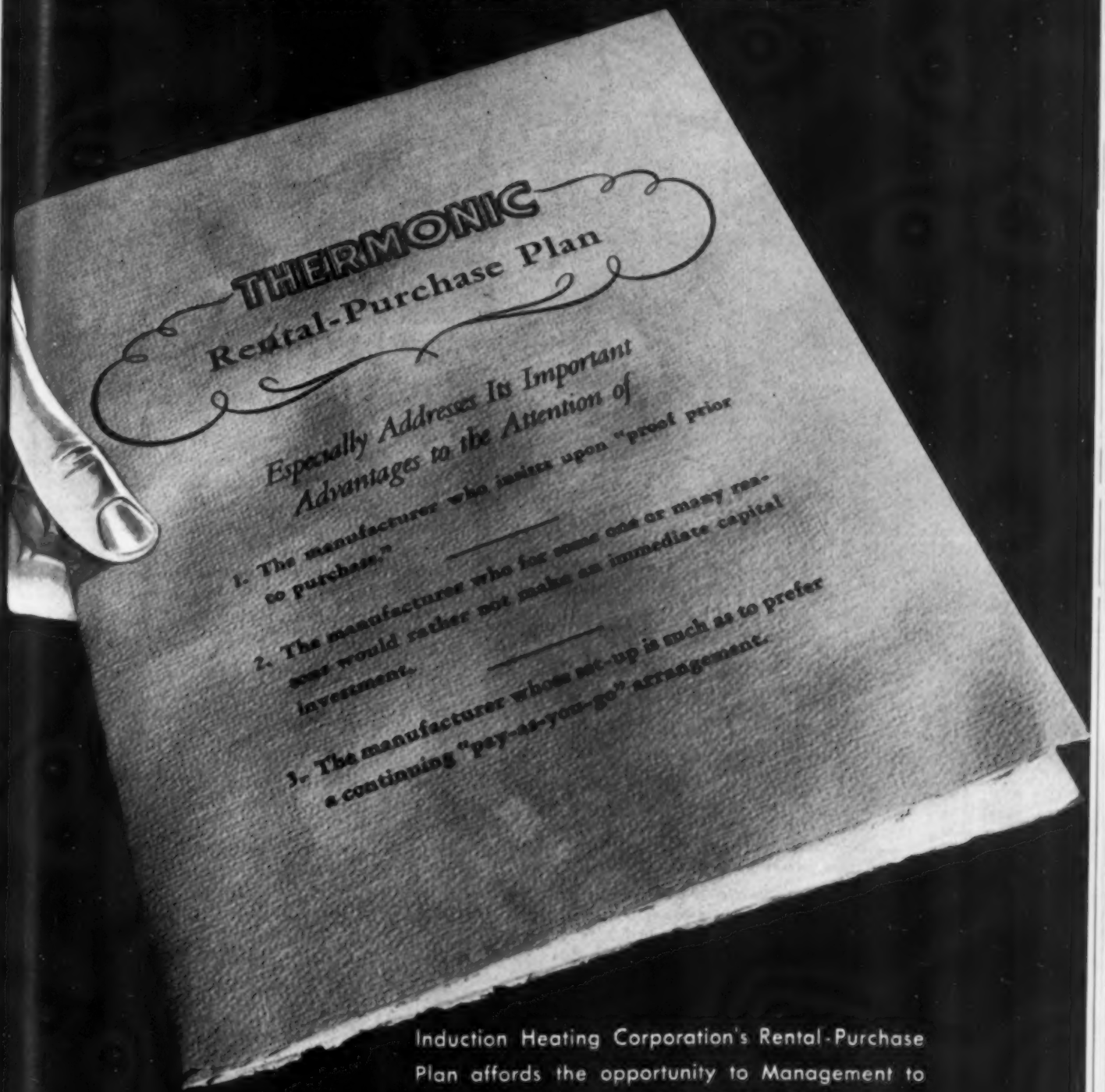
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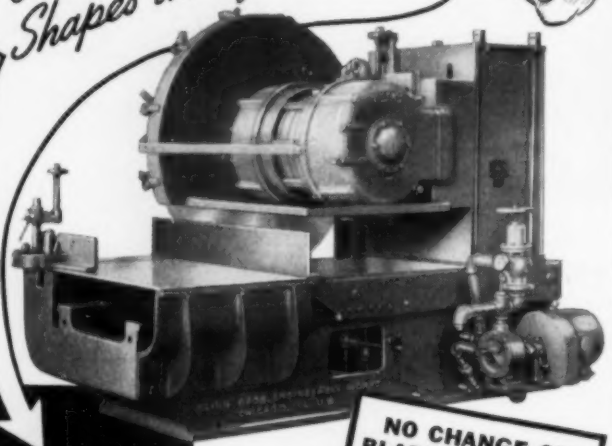

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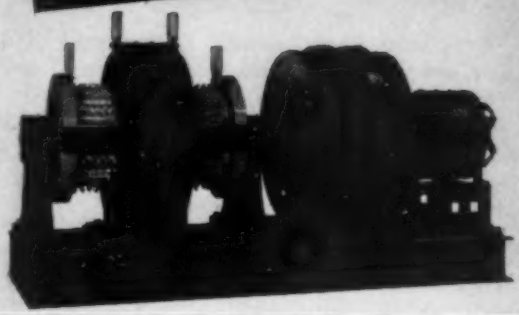

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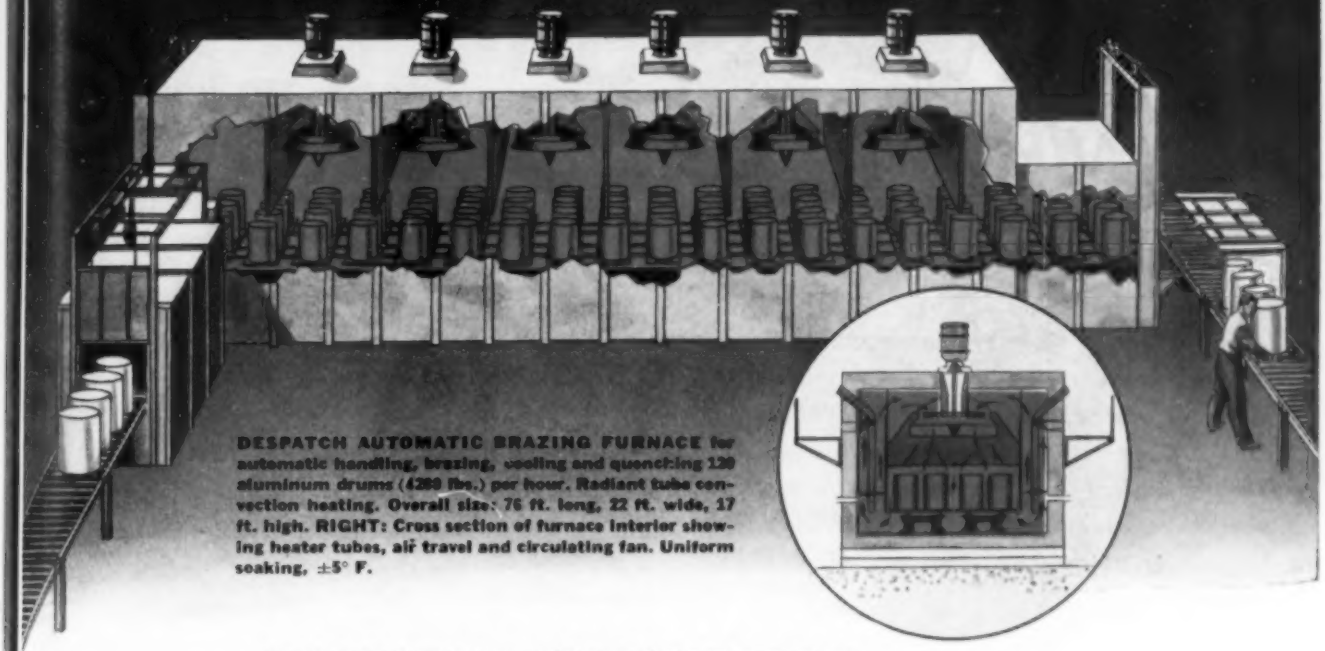
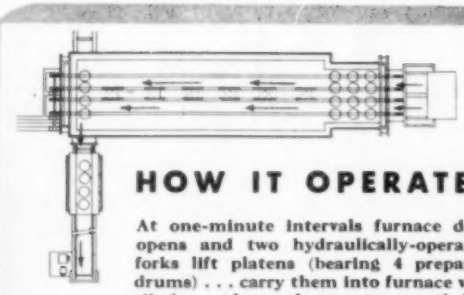
Brazes 4 Aluminum Drums per minute!



DESPATCH AUTOMATIC BRAZING FURNACE for automatic handling, brazing, cooling and quenching 120 aluminum drums (4280 lbs.) per hour. Radiant tube convection heating. Overall size: 76 ft. long, 22 ft. wide, 17 ft. high. **RIGHT:** Cross section of furnace interior showing heater tubes, air travel and circulating fan. Uniform soaking, ±5° F.

Another DESPATCH-ENGINEERED 100% Automatic FURNACE TIME-CYCLE CONTROLLED



HOW IT OPERATES

At one-minute intervals furnace door opens and two hydraulically-operated forks lift platens (bearing 4 prepared drums) . . . carry them into furnace vestibule . . . lower them onto smooth hydraulic operated intermittent conveyor. As forks withdraw, furnace door closes and conveyor moves load forward 30".

In this manner conveyor carries load through 5 convection-heated zones of control to provide correct preheating, soaking and cooling.

In each section heat is provided by correctly spaced gas-fired radiant tubes mounted on walls. Recirculated air is drawn up and around radiant tubes, then driven downward by powerful circulating fans to provide clean, uniform, accurately-controlled heatflow through each heating section. Independent controls regulate temperature.

When drums reach end of cooling section, quench and furnace doors open, rail-device lifts pallets from conveyor, and hydraulic pusher thrusts load laterally from chamber onto motor-driven conveyor.

Conveyor carries drums rapidly to spray booth. Doors then descend, drums are spray-quenched 30 sec. Exit door then opens and completely brazed drums are discharged.

Requiring no human effort save for placing drums at chamber entrance, this Despatch-engineered Brazing Furnace *automatically* brazes, quenches and discharges aluminum drums (24" diam. by 35" high) at the rate of 4 per minute . . . over 2 tons per hour!

ROBOT TIMER CONTROLS ALL OPERATIONS

To make this high production possible, all operations are controlled to the second by ingenious time-cycle mechanism. Control of heatflow and temperature, conveyor movement, synchronized operation of doors and load-pushers, time-and-temperature pre-heating, soaking and cooling, operation of quench—all are coordinated and controlled by a master "robot" timer housed in a single cabinet.

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Riding in pairs on special supporting pallets, drums are carried through 5 independently-controlled heating sections (radiant tube heated), cooled to 960° F., then quickly discharged into spray quench. Four complete drums are admitted, and discharged, every 60 seconds.

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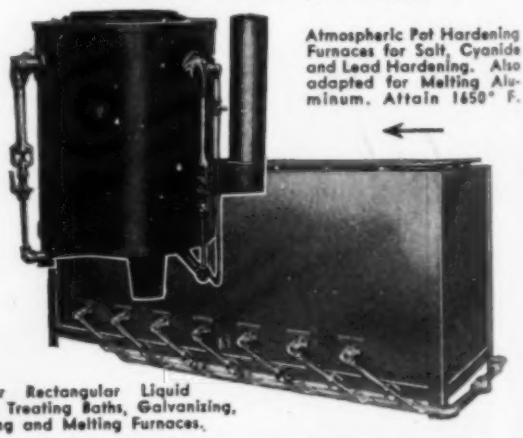

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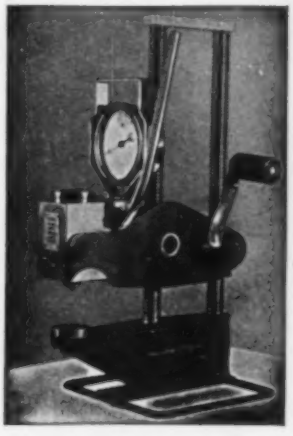

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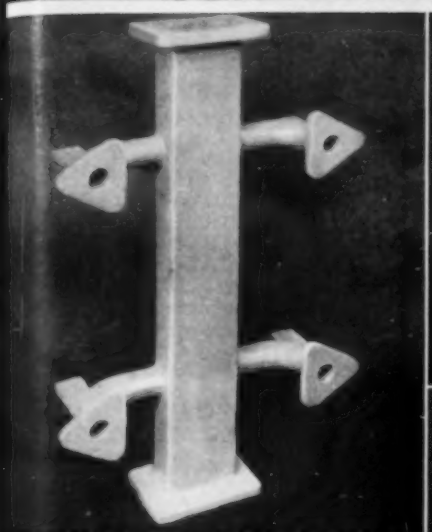

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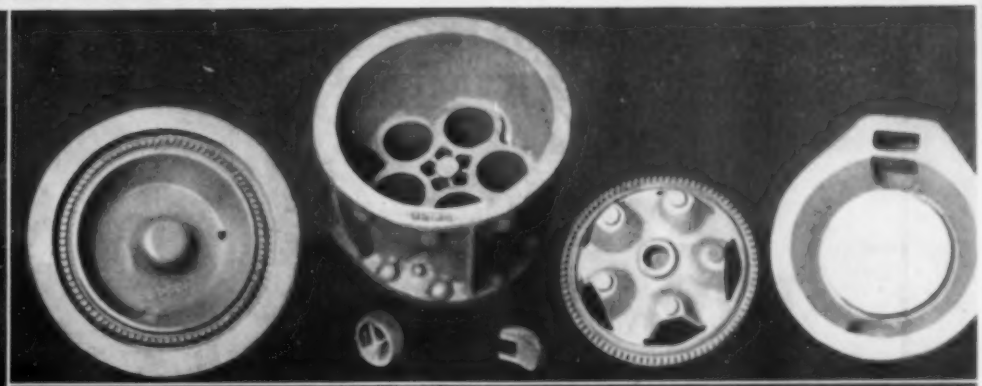

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A RETURNED War Veteran commenting on a dinner in his honor remarked: "If the soup had been as warm as the wine—and—the wine had been as cold as the roast—if the Hostess had been as pretty as the Waitress—and—the Waitress had been as willing as the Hostess———it would have been a damn good party".

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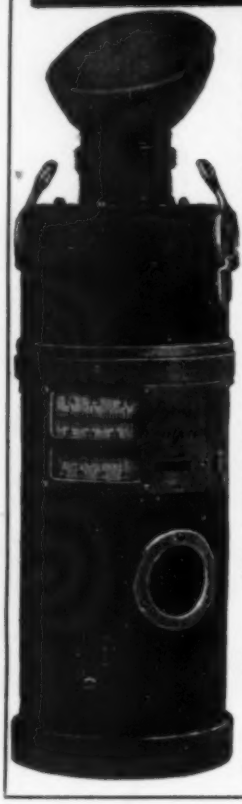

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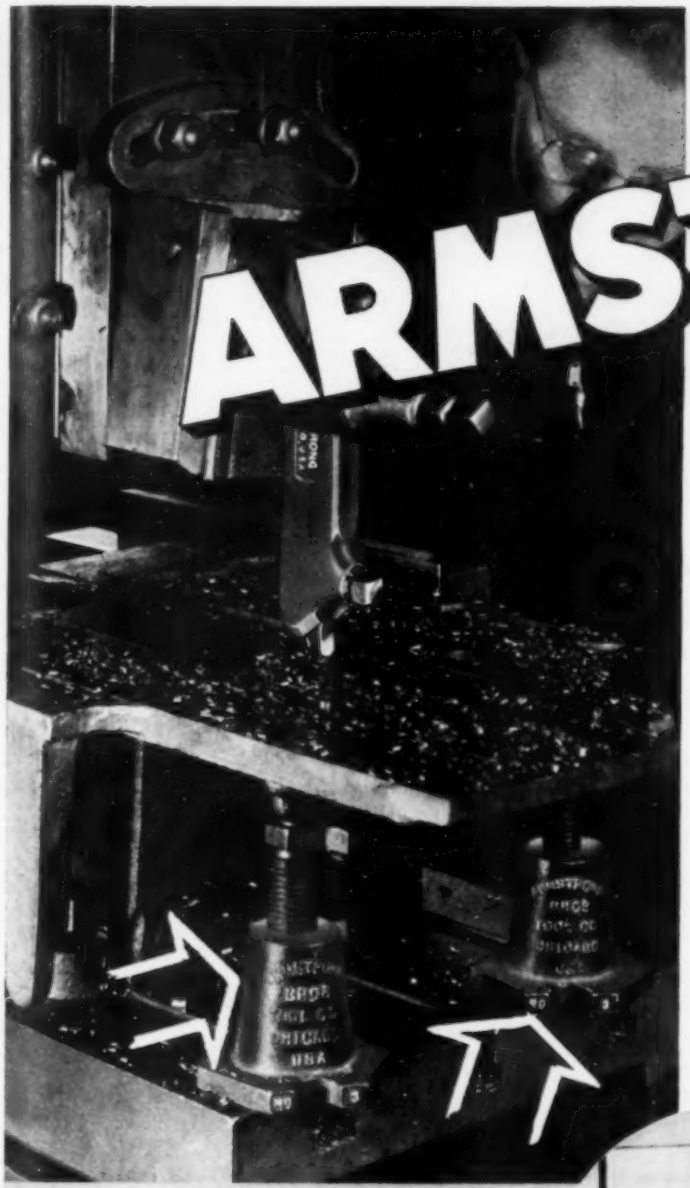

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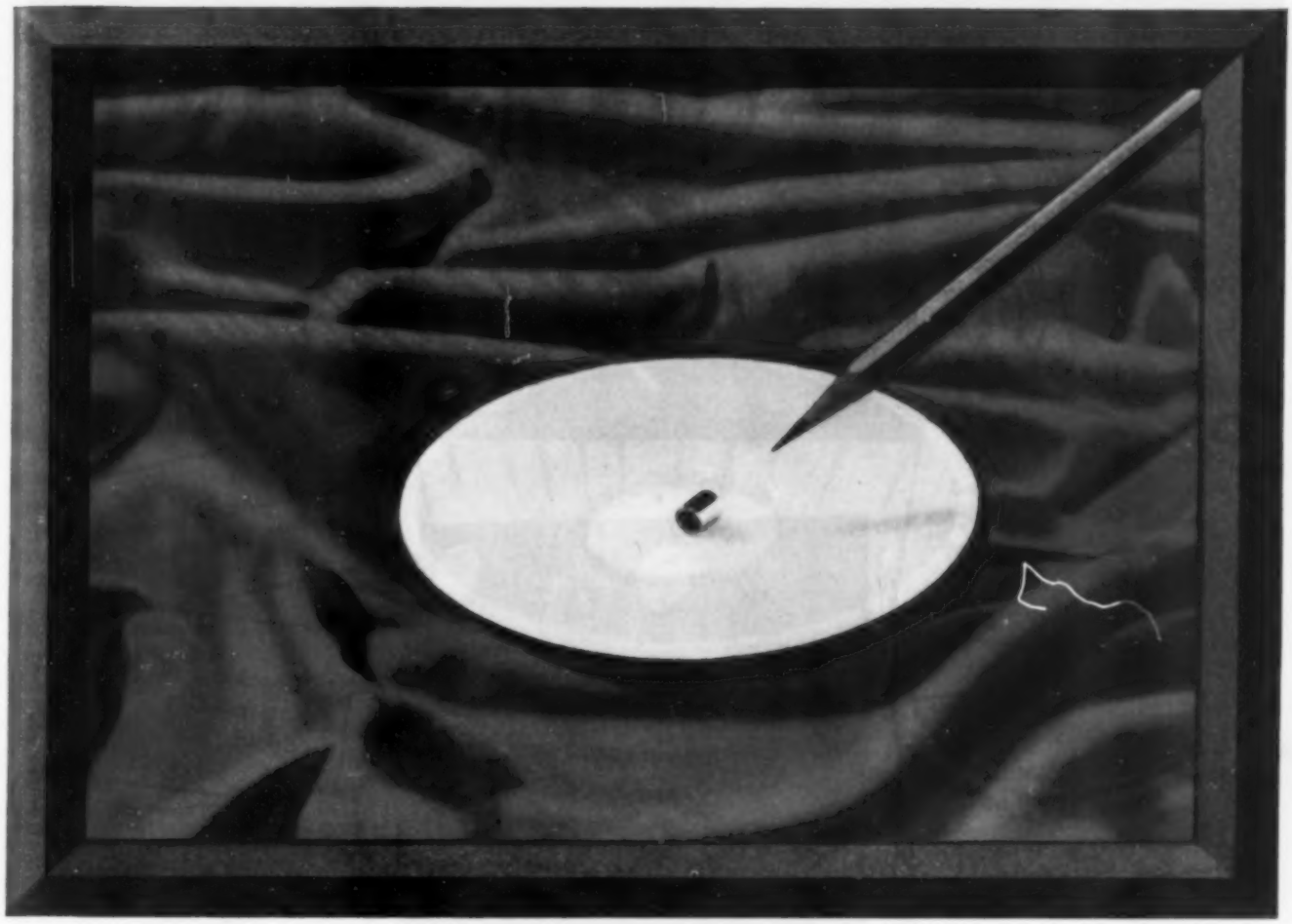

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